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THE WATERSHED AS AN ENTITY FOR DEVELOPMENT PLANNING[1]

JACK L. KNETSCH AND WILLIAM J. HART
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THE watershed concept has been increasingly brought before the public as being relevant to the solution of a multitude of natural resource problems. This is true not only of various small watershed programs, such as those conducted under the Small Watershed Protection and Flood Prevention Act (P.L. 566), but for studies and programs concerned with other types of social and economic advancement as well. This has included the common acceptance of the drainage basin as the most appropriate physical setting for the study and encouragement of comprehensive resource development and general economic development.[2]

The rationale of organizing programs for limited geographic areas defined by the flow of water in streams was initially considered as the filling of a flood protection gap between soil treatment measures on agricultural land and construction of large structures on the main stem of a river system. The small watershed concept began to assume national prominence in the ideological war waged by the agriculturists to avoid large structures in the Great Plains region during the mid-1930's. The idea was further strengthened by successful working examples of multiple-use watershed districts such as the Muskingum District in Ohio. It has been argued in this connection that the use of small physiographic units keeps the control of the decision-making machinery close to the grass roots. The concept of a watershed is now often advanced as a useful spatial unit not

[1] This is in part an outgrowth of a paper submitted to the Conservation and Land Use Seminar at Harvard University in 1959 by the authors together with Blaine O. Halliday and George E. Stroup. Appreciation is expressed to them, to Ayers Brinser, and to members of the TVA staff for helpful suggestions on the content of the present paper. Statements herein are those of the authors and do not necessarily represent the views of the Tennessee Valley Authority or of the Nevada State Park Commission.

[2] Examples of the use of a watershed for such purposes include river basin study commissions, several tributary river development associations on the Tennessee, and the Yellow Creek Watershed Authority in Mississippi.

only for the control of floods, but also as a guide to investment for: (1) the construction of small structures to serve municipal and irrigation water supply, (2) wildlife and recreation development, (3) promotion of the benefits of forestry or electrical power, (4) the raising of farm income, (5) increasing industrialization, (6) promoting general economic development, and a host of other physical and social goals.

Even though the public has come to accept the watershed as a convenient and seemingly appropriate spatial unit for resolution of problems, the term may define such a vast body of possible problems that we believe there is a need for constant reevaluation of this approach. The topographical watershed may or may not be most relevant for use as the basis for study and for problem solution.

It is the purpose here to examine the watershed as a useful unit for problem understanding and for program planning. We will take as an example one particular watershed—Chestuee Creek, Tennessee—and examine some of the ways that public attention is focused on a certain problem, or series of problems, and consider the appropriateness of the watershed as a unit to deal with them. Our main proposition is that this particular physical boundary is largely arbitrary with respect to many kinds of problems and programs that are often dealt with in a watershed and that problem solution may be better handled on some alternative basis.

I

The topographic watershed considered—Chestuee Creek—is located in lower east Tennessee, encompassing parts of three counties about midway between Knoxville and Chattanooga. This watershed was selected by the Tennessee Valley Authority (TVA) in cooperation with state and local agencies as a demonstration and research watershed to be used in TVA's resource development program.

In the Chestuee Creek watershed the initial problem defined by the local people as a basis for development work was the frequent flooding of the bottom lands. In addition to the felt need for water control, other problems which could be related to a program of resource development in the area included low family income of residents, inefficient farming units and poor levels of management on farms, limitations to off-farm employment, and low educational levels and deficiencies in the school systems.[3]

[3] The development program carried on in the watershed recognized these needs to some degree, especially in the field of public health where county health units were established. Chestuee Creek was the first small watershed project conducted by TVA and later program formulations have included considerable modifications.

"Social and Economic Materials Relating to Chestuee Watershed and Vicinity" (prepared by an Interdivisional-Interdepartmental Committee of TVA and the Uni-

The Chestuee watershed is approximately 27 miles long and averages about five miles in width, a total of 134 square miles, or 85,000 acres, in size. The topography and flow of the Chestuee watershed, typical of many areas in east Tennessee, is characterized by a stream having a small channel capacity, narrow flood plain, and gently rolling lands rising from the stream to the steeper knobs which form the watershed boundary. The creek is part of the 2,500 square mile drainage area of the Hiwassee River and joins the Hiwassee shortly above the reach of Chickamauga Reservoir on the Tennessee River.

About three to four percent of the area is flooded following severe storms. A major portion of the flood plain has been cleared and is or has been used for crop production. Because of the flood hazard, the flood plain lands are used in large part for crops of lower value and receive little investment in production practices, such as fertilization.

Chestuee watershed is also a part of a rural area dominated by small farms with low incomes. Approximately 6,500 people live within the bounds of the watershed. About 45 percent of the households are engaged solely in farming, although agriculture accounts for only about 13 percent of the total income of the area. Englewood, with a population of 1,545 in 1950, is the only town located in the watershed. The more important urban centers for the people of the area are Athens, Etowah, Madisonville, Calhoun, and Sweetwater—all located just outside the watershed boundary. These towns, together with Oak Ridge and Alcoa, somewhat farther away, serve as the most important sources of off-farm employment. Per capita income in the three counties whose political boundaries cross the watershed boundaries averaged $783 in 1951, as compared to $1064 for Tennessee and $1584 for the United States.[4] "Nearly half the farm operators of the area reported eight years of school or less."[5] In addition, social studies have shown that school attendance, teachers' salaries, and citizen interest in education are all low.

Thus, the people of the Chestuee Creek area face a whole range of problems.

In proceeding to a further examination of the program formulation in this area our first concern will be the economic aspects of the watershed related to the flood problem. This does not preclude inclusion of other nonwater-oriented factors which are important for various reasons. However, as flooding is the essential reason for dealing with the area in terms

versity of Tennessee, Knoxville: Mimeo., 1953). This study, which will henceforth be referred to as *The Benchmark Study,* lists statistical information concerning the Chestuee area in convenient form.

[4] *The Benchmark Study.*

[5] John Blackmore, "A Watershed Development Program for the TVA" (Doctoral Thesis, Harvard Univ., 1954), p. 242.

of a watershed, the economics of dealing with this problem is a prerequisite to our evaluation.

II

An examination of recorded data indicates that overbank flooding along the main channels of Chestuee Creek and its principal tributaries has been frequent and that some damages have occurred. During the thirteen-year period from 1944 to 1956 for which records are available, the creek has been in some stage of flood during a portion of each year. Major floods were recorded in 1946, 1949, and 1956. The damages which resulted from these floods were nearly all agricultural—no urban developments were within the scope of even maximum inundation, and downstream effects were negligible. Although the flood of January 1946 covered the largest acreage (4,000 acres), the 1949 flood, which inundated 2,836 acres, was the most damaging, as it occurred during the crop season. To be consistent with the TVA data on which this analysis is based, the flood plain for our purposes will be taken as the area covered by the 1949 flood, and the magnitude of damages in this flood is taken to be indicative of those which flooding of Chestuee Creek will produce.[6]

If the problem of flooding is to be examined, the relationship of the uplands to the flood plain must be examined. It must be determined if the upland areas contribute materially to, or are a factor in, the occurrence or intensity of inundation. Such interdependence of land use and water regimen has, for good reason, been cited as a prime reason for dealing with flood problems on the basis of an entire watershed.

In the case of Chestuee it appears, from the data on the watershed, that there are some stream regimen improvement benefits that would result from the incorporation of conservation practices on the uplands, but they are not really important to the solution of the flood problem as such. The returns stemming from such investments are likely to be relatively small in terms of flood protection. Other benefits from such action may be quite large, and hence there may be very good reason for giving attention to the uplands from the standpoint of improving farming practices, farm tenure arrangements, employment, and so on, but here we are interested in the relationship to flood protection.

Since the uplands are susceptible to substantial improvements through adjustments in land use practices, such improvements would reduce erosion and the silting of the stream channels. However, original survey data do not indicate a large acreage of seriously depleted lands and the type of flood damage is not the type usually attributable to floods carrying heavy

[6] TVA, "Preliminary Report—Flood Damage Reduction in the Chestuee Creek Watershed" (Rept. No. 0-5831, Knoxville: 1958, revised Jan. 1959).

silt accumulations from the upland areas. These differences are shown in a 1945 TVA report which stated:

> The uplands are susceptible to substantial improvement through adjustments in land use practices. Such improvements will reduce erosion and the silting of the stream channels, but will not sufficiently reduce the flooding in the valleys to provide effective water control for valley lands.[7]

It was concluded that even complete installation of economic farming practices on the uplands would not remove the danger of overbank floods even though silt load reduction could be effected. For these reasons we may, without too large a distortion, confine our attention to those problems on the flood plain which are affected by the water regimen. As the available flood history of the stream was limited to a thirteen-year period, the assumption is made for the purposes of this analysis that these records sufficiently represent a long time series of flood histories.

With this information at hand, the magnitude of damages sustained on the flood plain was determined to ascertain the kind of control measures which would be feasible. The procedure followed, briefly, was to estimate the total yearly value accruing from present land uses by examining the number of acres devoted to various uses and the net value per acre for each use. This was found to be $28,796. Crop damages and remaining net value of crops on the flood plain were then calculated using flood histories and percentage damage factors.[8]

It was felt that the relevant figures would be the net crop value less damages. These were obtained by subtracting the flood damage from the established total net value per year. These figures represent the value of return from the flood plain and hold the primary interest for us in much the same way as net rather than gross returns do in most economic activities. The annual damage from flooding alone ranged from $679 (1947) to $8,144 (1949) and the average damage was found to be $3,484. In addition to the loss to farm crops, damages to roads, bridges, and fences have been estimated at $600 per year.[9] Thus, the total average annual flood damage in Chestuee Creek is estimated to be $4,084.

The next step was to examine possible alternative measures which would be designed to give varying measures of control to the flow of Chestuee Creek and compare the annual costs against the annual benefits.

Probably the most obvious of possible flood control measures would be engineering measures such as channel enlargement, channel clearing, detention reservoirs, small headwater reservoirs, and cutoffs on the main

[7] TVA, "Initial Phases, Chestuee Watershed Project" (Knoxville: 1945), quoted in Blackmore, *op. cit.*, p. 83.

[8] Unpublished TVA data.

[9] TVA, "Preliminary Report," *op. cit.*, p. 5. All data used in reporting the engineering alternatives are derived from this publication.

channel. Again, without presenting detail, the two most feasible engineering measures were found to be channel enlargement and channel clearing. On the basis of their costs and resulting benefits, neither of these measures provides an economic return. Several other engineering alternatives were investigated by TVA, including a series of small detention dams, several large reservoirs, and construction of cutoffs to eliminate the large meanders in the lower portion of Chestuee Creek. It was concluded, by TVA, that these methods were all even less effective and less economical than the channel enlargement and channel clearing alternatives.[10]

Soil surveys, topographic maps, cropping and forestry studies show that the flood plain lands are suitable for the production of corn, alfalfa, small grains, pasture, and yellow pine. Since strong interdependence between the upland and flood plain has been assumed to be insignificant and engineering alternatives have shown little promise of being economic, it seemed logical to approach the problem of flooding by looking at what would happen if present flood plain land use patterns were altered to minimize the effects of periodic flooding. Thus, the returns were considered if all land on the flood plain were put into improved pasture or in yellow pine, which are relatively unaffected by flooding. As a point of comparison, some more intensive land use patterns were formulated which would produce high enough returns so that the residents on the flood plain would be better off, even with flooding, than they are now. For the purposes of this paper, it is assumed that the best use would be reached if all the land on the flood plain were converted to the same pattern—all pasture, all yellow pine, or all in the same rotation. The difficulty in reaching this state of use and the possibility of higher returns under combinations of practices or practices not considered here are recognized. The costs involved in converting the present 816 acres of forest land were considered to be unimportant, as available data show that the value of forest products sold would about equal the cost of clearing.[11]

The average net farm returns after deduction of flood damages of the land in the flood plain were found to be $25,312 with the land in its present use. If the entire flood plain were converted to improved pasture, which would sustain little damage as a result of floods, the total net return for the 2,836 acres would be expected to average $26,701 per year. The conversion of the flood plain to yellow pine seemed feasible from the standpoint of damage reduction, and also as a result of the establishment of a large pulp plant nearby. However, the total net return would average only $11,344.

In order to compare results with a higher intensity use, a rotation sys-

[10] *Ibid.*
[11] TVA, Unpublished data.

tem consisting of six years in pasture and two years in corn was selected. This particular rotation was chosen because it seemed to offer high returns while being consistent with the soil conditions of the flood plain lands. If this rotation were established on the entire flood plain, 2,127 acres would be in improved pasture and 709 acres would be planted to corn during any one year. Net returns from this land use pattern would average $37,842—substantially greater than either the original or the other land use changes considered.

In view of the increased return that can be expected under the high-return rotation system it appeared important to examine physical flood control work in connection with these changes in land use. However, even with these increased returns, such work was still found to be uneconomic.[12]

Essentially, then, the conditions in this watershed seem to be such that the most significant increase in returns from the flood plain lands results from a change in the land use pattern to a more intense cultivation of those lands. This involves larger investments in production practices and a shift in land use from large areas of land presently producing little if any profit to crops yielding greater net returns. Although a complete conversion is not expected—nor is it likely to be economically justified on each particular farm—the extreme is examined to determine the maximum potential increase in income that could be developed.

These comparisons show that the greatest benefit that could be obtained in the flood plain would be derived from a more intensive use of flood plain land with no investment for flood reducing measures. This conclusion suggests that the flood damage problem is not of too great importance by itself, for seemingly the best possibilities for dealing with the flood problem have only incidental relevance to the fact that the area is located on a flood plain. The examination of the flood problem has served in large part to redefine the problem, in that the course of action indicated is not to treat the problem of inundation but rather to raise farm income quite apart from, or in spite of, the flooding. Changes in the crop pattern which result in greater farm income are probably just as relevant to farmers not subject to flooding as to those who are.

The implication seems, then, to be that if the problem of flood hazard is considered, the solution centers on the raising of income on the flood plain farms through better farming measures. But such measures could most certainly be carried on through already existing agencies and insti-

[12] A possible alternative to overcome the uncertainty problem and the considerable resistence to shift in land use in the absence of stream improvement work may be to initiate some form of insurance scheme to offset the effects of the flood hazard. Such a program would allow farmers to make fuller use of the flood plain lands through reduction of uncertainty.

tutions along other geographic boundaries quite apart from any watershed considerations. Thus, from the present point of view, the physical boundaries of Chestuee Creek watershed do not serve a very useful purpose in the design of programs on a multi-function, multi-level, and multi-time basis.

The raising of farm incomes, however this might be accomplished on the flood plain, is but one alternative that could be incorporated in a development program to deal with the problems of the area. Such a program immediately involves more than the original problem of flooding and focuses attention on other programs that might handle the total situation more effectively. After all, a large part of the present income of Chestuee people comes from off-farm employment. Other ways to deal with the situation, either as separate programs or in various combinations, might be: a regional economic study to point out sources of economic difficulty and possibilities; a county program aimed at education improvements; area development programs to increase off-farm employment and raise family incomes; and a state program to bring about agricultural adjustments and raise farm incomes.

III

The array of alternatives stems in large part from the nature of the different problems that are present. There is in the series of problems being faced, the real difficulty that some of the problems pertain to the watershed as such, but others concern a trade area, a county, a school district, or an employment area—entities of heterogeneous and complex spatial alignment. Boundaries associated with different problems may overlap, or may bear little or no relationship to one another. Problems of county government, for example, bear little spatial relationship to those of the watershed that includes portions of several counties. In addition, many problems of the area are local manifestations of problems of state, regional, or national concern. Thus, a hierarchical pattern is superimposed upon the already complex local pattern of problem alignments and makes inherent a degree of arbitrariness to the area within which examination or action is focused.

A further complicating factor in problem delineation results from the interrelationships between different recognized problems. Efforts directed at resolving any one of these often involves others. The effect may produce a positive result or a negative one in which other problems are aggravated or even new ones created.

Obviously, then, the recognized problems are part of a bundle of interrelated problems—which we might term the problem complex. As the nature of the problem complex is built largely on social value judgment

defined through the political process, it can be expected that the parts of this complex will change in relative values over time. A good case can then be made for the view that "for the most part, order is an abstraction or an assumption created for the purpose of making useful, if partial, decisions, to direct the course of change."[13]

In this discussion, we are particularly interested in the government agency, at any level, as a direct operating instrument of society, which is in a position to concentrate technical skill on the resolution of certain groups of these problems. As government has to face a desire to alter conditions in a portion of the entire area, in order to bring about better general conditions in the Nation, it should be aware of interrelationships between different problems and the values which are attached to them in formulating agency programs and policies.

Government, in the case of the United States, usually does not act spontaneously to attack the problem complex as it may exist but rather in response to felt needs. Recognition may come from a portion of society outside the affected area. As an example, happenings in Chestuee Creek at the turn of the century affected few people outside the watershed. Now, however, out-migration of Chestuee people has extended the effects of happenings in the watershed as far as Cleveland, Detroit, and Chicago. It follows that the portions of the problem complex recognized by the larger society may well be somewhat different than the portions recognized by the residents of the area itself.

Governmental action operates within certain limits imposed by society. These limits may be partially the result of prior action by society or may be otherwise inherent in the current environment. The rational range of possibilities is defined in a practical sense largely by some more or less obvious economics and by the political process. Feasibility certainly becomes a relevant consideration here, but it represents a necessary and not a sufficient criterion in the planning process since other considerations should be taken into account.

As the felt need is translated to attack the problem complex through definite programs, the necessity to make choices must be faced. The exact problem or problems to be attacked must be decided upon—such as controlling floods in Chestuee Creek or providing an intensive program of vocational training. This may be thought of as the scope of the program. Also, the geographical area in which the program is to operate must be determined. Although it is generally felt that the effects of a program may extend outside of the specific area under study, usually a choice must be made as to where the effects of any program are to center. The

[13] Ayers Brinser, "Planning Unit Budgets" (Unpub. Conservation and Land Use Seminar Paper, Harvard Univ., undated), p. 1.

Small Watershed Act is, in a sense, such a choice, defining the type of area to be involved and the problems to be dealt with.

Some combinations of program scope and geographic area will be better combinations than others. They may be judged by the economy and efficiency with which problem resolution is accomplished with the investment made by society, where efficiency is broadly defined so as to take account of welfare considerations, equity, and so forth.

Spatially, no chosen area will be completely suitable to the resolution of all parts of all problem complexes. The choice to be made is essentially that of choosing the best compromise. For example, a small watershed to deal with flood control and farm management problems may not provide a reasonable basis for dealing with the educational needs of the area, while county or township lines may suit the latter but be completely inappropriate for flood control. Or economic units and social communities based on a church or trading center may be suitable for meeting social problems but not physical problems. Consequently, in dealing with problem complexes relating to public resource development, the question of what is the relevant area of work takes on considerable importance. The choice of the watershed presents one answer to this question.

A watershed by itself has significance only as a basin of a stream—a physical entity with boundaries set by nature. So long as development is strictly limited to activities directly related to the water regimen, there may be no serious conflicts of area boundaries, i.e., considering a watershed as opposed to other alternative delineations. However, as other activities are included in the program, the watershed begins to lose its unique relevance as the basis for developmental activities, for these other aspects may have less and less relevance to water. A similar lessening of the importance of the watershed per se occurs as the programs actually aimed at water-oriented problems begin to affect other aspects of the area. Such a situation may occur, for example, when the solution of a flooding problem encompasses change in land use and possible changes in farm organizations which may consequently have significant effect on the local economy. The watershed also becomes less relevant when water development projects become important to people outside the watershed, as in the case of reservoirs used for recreational purposes by people in a large urban area, or for water supply to such an area. The watershed and its hydrology are not ends by themselves, but only have a degree of unity with respect to a portion of the physical environment.

A further limitation of the watershed as a basis for planning is the absence of effective devices and institutions for raising and settling value, goal, and other policy issues. Since watersheds frequently overlap existing political boundaries, as they do economic sectors, they are affected

by various separate political bodies that may or may not lend themselves to effective coordination. This absence of political and administrative institutions with area jurisdiction or responsibility corresponding to the spatial arrangement used to discuss and resolve watershed problems may hamper the effectiveness of the program.[14] It has been argued, within the limits of Public Law 566, that the ability to focus on a single physical unit and the ability to gather a wide base of professional disciplines around a single physically defined problem area will materially aid in the planning process. While there is some validity to this argument, this arrangement further complicates the already bewildering complex of overlapping jurisdictions, which make unitary planning and orderly budget making much more difficult. The absence of constituted government also makes it harder to fix responsiveness, control, and responsibility not only in the formulative stage of development of the watershed area, in which differences in interest can easily develop, but throughout the duration of the given program when, for example, questions of maintenance of engineering works or of finanacial responsibilities arise.

The usefulness of the watershed is thus subject to a number of limitations in carrying on resource development projects, even though they may initially be oriented to water regimen. In many cases the language of "areal unity and development" may be used to formulate programs that have essentially separate functions and particularized responsibilities.[15]

Regardless of these and other shortcomings of the watershed as a basis for dealing with area resource development problems, this choice may be the most appropriate in many situations. As we have pointed out earlier, any choice that is made in this connection is at best an arbitrary choice. The important consideration here is that the alternative solutions to the given problems should be examined and evaluated and a choice made which will assure some satisfactory degree of efficiency.

The watershed may be an efficient basis for planning, not because of its physical attributes alone, but also because of the popular appeal which may allow solutions to problems to proceed in a more amiable manner than another type of program. There is the real danger, however, that water-oriented programs could be initiated at the great cost of ignoring other more important problems.

If the problems to be dealt with are closely related to, say, water management or flood control, the watershed may prove to be the logical entity even if these programs extend into other areas of activity. However, if it becomes apparent that the watershed phases are but a segment of a

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[14] Cf. Norman Wengert, "The Politics of River Basin Development," *Law and Contemporary Problems*, 22:258-75 (Spring 1957).

[15] *Ibid.*, p. 261.

series of other difficulties, it may be justifiable, and indeed more effective to redefine the problems and deal with the critical issues in another and possibly more efficient manner. Thus, flood hazards and soil erosion may be parts of a more general problem involving low farm income and possible low educational levels that can be resolved more adequately on county or some other regional lines which would treat the watershed problems as a subissue.

If an important program concern is general economic development, as it often is, then the inclusion of trade and service centers in the area of concern seems indispensible. Such centers may often usefully be the focal point for the area. This is especially true as present and potential labor and product markets are often closely tied to urban areas.[16] The realities of the world seem very much to favor looking first at the over-all problem of economic development in the context appropriate for this and to then look at how water development projects might be undertaken.

Another choice problem that must be faced is that of areas of various sizes, since most areas may be considered as part of some larger system. A small watershed may prove to be effective as a basis for carrying out specific objectives, but prove to be less efficient than some larger area that would consider a wider portion of the problem complex with possibly only a relatively small increase in the total investment. However, the larger unit may also be subject to serious diseconomies of scale owing to the multiplicity of private and public operating units with which it must deal.[17] Each unit of different size will require different considerations and the economics of program output in terms of problem solution and the politics of program planning become important factors in the decision-making process.

Because of the involved relationships among problems faced by society and the lack of a clear outline for the resolution of these problems, it appears that there may be little assurance that a single agency program or objective will formulate satisfactory solutions to problems even if those examined are restricted to resource development. What is apparently needed is an interplay among the various public bodies or increased latitude in individual agency programs, and a comparison of program alternatives if society is to derive the greatest benefit from its governmental structure.

[16] Cf. John R. P. Friedman, *The Spatial Structure of Economic Development in the Tennessee Valley* (Chicago, Univ. of Chicago Press, 1955).

[17] It may be noted here that if solutions to problems in small areas are to be used as the basis of programs for more extended regions, there may well be some difficulty of applicability. For example, chance location of a small industrial plant or production of products with very limited demands may offer solutions to problems in a small area that would be inappropriate as general solutions for larger areas.

THE MOBILITY OF RURAL LABOUR AND THE SETTLEMENT OF NEW LAND IN UNDERDEVELOPED COUNTRIES

E. K. Fisk
Australian National University

MOST underdeveloped countries are faced with problems of overpopulation and underemployment in the rural sector of the economy. These are complex problems, for apart from the difficulty of finding alternative employment for the (usually) vast numbers involved, there are the difficulties deriving from strong rigidities in the social and economic structure of life in rural villages, and the high degree of immobility typical of much rural labour under such conditions.

There are some underdeveloped countries where the problem of rural overpopulation is an absolute one; where most of the readily arable land has been taken up, and the only large scale potential outlet for excess rural population is to industries other than agriculture. However, such countries are still in the minority amongst the underdeveloped countries of the world. A large proportion of the underdeveloped countries still have substantial resources of agricultural land available for settlement, often in areas remote from the main centres of rural overpopulation.

This paper is concerned with the causes of the immobility of rural labour in underdeveloped countries, and with determining the most economical means of overcoming it for purposes of encouraging the migration of surplus population onto unused land resources. It is concerned, therefore, not with overcoming the immobility of rural labour in general, but with inducing mobility amongst a specific group of people for whom migration is particularly necessary.

There is no doubt that the immobility of rural labour is a very real problem in such a context. A change of location of employment, where any substantial distance is involved, is a serious and difficult matter for an impoverished member of an overpopulated rural community. There are the purely social difficulties, which make a man reluctant to leave the community with which he is familiar. There is the question of social security, in that migrating amongst strangers means abandoning the security afforded him and his family by their unwritten rights under the extended family or other such social institution; these would, in most cases, assure him some form of shelter and minimum subsistence in times of sickness, crop failure or other catastrophe. There is the problem of cost of travel to the new area for himself and family, and of return in the event of failure. There is the problem of finding the capital to meet the cost of housebuilding, of clearing and preparing the new land for culti-

vation, of tools, equipment and planting materials. There is the problem of supporting himself and family until production on the new farm reaches a minimum subsistence level. In many cases there will also be the problem of learning new agricultural techniques required by the new environment and the types of crops to which it is suited.

Over and above these individual problems, there are other communal requirements that will be necessary for the successful settlement of new land in a remote area. These include such matters as communications, access to markets, and all the social, religious and economic institutions required by a productive community.

Virtually all these problems and requirements can be met by the provision of adequate capital for investment. There are three potential sources from which such investment may be derived: (a) The prospective settlers themselves, (b) other private investors,[1] and (c) government funds. In the modern world, outside the Communist block, there will normally be some element of investment from each of these sources in practically every new settlement by peasants, but the relative proportions contributed by each source, and the total amount of investment from all sources per settler, provide an extremely wide range for variation between individual settlements. In this paper consideration will be given in particular to two rather extreme cases, one in which the total investment from all sources per settler is very high, and in which a very large proportion of the investment is initially financed from Government funds, and one in which the total investment from all sources per settler is relatively low, and mainly financed by the settlers themselves. From these examples, and by reference to other intermediate types of settlement, an attempt will be made to derive certain principles that will be of value to planners faced with the problem of inducing the maximum mobility of this type with the limited resources, public and private, available for such investment in an underdeveloped country.

The Factors of Production

The situation is one in which there is a superabundance of rural labour in the overpopulated cultivated areas, and substantial resources of potential agricultural land elsewhere.

In this situation, two of the factors of production, land and labour, are in abundance. The overcrowding and underemployment in the agricultural sector is due not to the shortage of land, but to the shortage of developed land: that is to say, land in which the productive capacity has been raised by the application of capital.

[1] Such as retailers, produce dealers, transport operators and others providing essential services on a private enterprise basis.

However, in the vast majority of underdeveloped countries, capital is a scarce factor. Moreover, at least in conventional terms, it is particularly scarce amongst the type of settler with whom we are most concerned, the impoverished peasant from the overpopulated areas. Therefore, in the short term, capital tends to be the limiting factor.

One of the principal problems in inducing the type of mobility of labour here required, therefore, is economising in the use of the scarce resources of capital available. This can be done in two ways:

(a) The total amount of capital invested from all sources, per settler, may be kept as low as possible. However, this cannot be over-done, or the level of income from the new farms will be insufficient to provide a satisfactory standard of living for the settlers.

(b) The amount of capital available for investment may be augmented by utilising the saving potential concealed in rural underemployment for the formation of new capital somewhat along the lines suggested by Ragnar Nurkse.[2] Investment in the development of new land can under certain circumstances provide particularly favourable opportunities for the utilisation of this potential as will be seen from the following analysis, and considerable attention will be paid to the means of maximising these opportunities in the planning of land settlement.

In the following case study of land settlement in Malaya, some of the more important aspects of this problem will be examined, and an attempt will be made to derive certain general principles regarding the induced mobility of rural labour from overpopulated areas under conditions where capital is the scarce factor.

The Malayan Background

Malaya, thanks to the development of its rubber and tin industries, is by no means as poor as many of its neighbours in South East Asia, but it is nevertheless an underdeveloped country in the widely accepted meaning of the term. Most of the problems typical of an underdeveloped economy are to be found in Malaya in a relatively acute and rapidly worsening form. In addition, it has a series of special problems of its own, deriving from the plural nature of its society, and from the economic imbalance between the indigenous Malays and the immigrant races who have made Malaya their home.

The Malays, who comprise just over 50 per cent of the population (1957 Census) are predominantly a rural people, deriving their living mainly from very small agricultural holdings growing rubber, coconuts, rice, etc., and from fishing in coastal waters. The other races predominate

[2] Ragnar Nurkse, *Problems of Capital Formation in Underdeveloped Countries*, Basil Blackwell, Oxford, 1958 (6th impress.), p. 36 *et seq.*

in the towns and cities, in commerce, industry, mining, and the larger scale agriculture.

The estimates of per capita net national product and other similar figures, used to compare the relative wealth of Malaya with that of other countries, do not take this racial division into account. In fact, although it is still probably true that the rural Malays are better off than the rural communities of most other underdeveloped countries in the area, the difference is very much less than the per capita net national product figures would suggest. There are areas of acute poverty and serious overpopulation, and the position is becoming worse through the rapid increase of the Malay rural population. There is also in Malaya considerable growth of commerce, manufacturing and processing industries, and of capital investment in building construction, which is creating new employment opportunities in the towns and cities, but these are mainly enjoyed by the other races, and the offtake of Malays from the rural areas into the towns is still insignificant compared with the population increase. As a result, the per capita income of the rural Malays is declining, both in absolute terms, and relative to the position of the other races in Malaya.

However, there is as yet no pressure on the land. The population pressure affecting the rural Malays is the pressure on the developed land. There are still vast resources of undeveloped land, mostly under jungle, available for settlement. These resources could provide an invaluable outlet for the Malay rural population, if the necessary degree of mobility could be induced to effect its settlement on a large enough scale.[3]

This possibility has not escaped the notice of the elected government of Malaya, in whose electoral rolls the voting power of the rural Malays is predominant over all other racial groups combined. Nor has the matter been neglected in practice, either by the present elected government, or by the colonial governments that preceded it. Much has, in fact, been done, and very considerable financial and other resources are being devoted to various programmes designed to facilitate the settlement of new land. However, although it is clear that the scale of new land settlement planned should go a considerable distance towards relieving the pressure of increasing rural population, it seems unlikely that it will be sufficient to remove that pressure entirely, much less to effect any significant relief for existing overcrowding in the developed agricultural areas. What is more, the scale of public investment per settler in certain of the Malayan

[3] The inducement of mobility of rural Malays into urban employment is also an important, though quite separate, question. The growth of Malay rural population is such that both potential opportunities for offtake of excess rural population must be exploited. In the following, the growth of rural population is taken to refer to the residual increase after deducting the maximum anticipated offtake into urban employment.

settlement schemes is higher than most underdeveloped countries could afford in a large scale settlement programme.

The question is, therefore, whether it would be possible to design an effective and worthwhile land settlement programme, whilst effecting substantial further economies in the capital cost to the State. There is evidence that strongly suggests such a possibility.

Types of New Settlement

New settlement that is currently taking place in the rural areas of Malaya can conveniently be classified into four types, viz:

(a) Unassisted settlement, in which the mobility of rural labour is autonomous, and there is no organized financial assistance by government over and above the provision of normal services.

(b) Land improvement schemes, in which the land is improved at government expense, as e.g. by irrigation or drainage schemes, together with the provision of certain facilities and amenities such as roads, schools, agricultural extension services, etc., but in which little or no direct financial aid is given to the individual settler.

(c) Subsidy schemes, such as the Rubber Industry (Smallholder New Planting) Scheme, which provides a subsidy of $400[4] per acre to selected new planting schemes where groups of individuals plant substantial blocks of new rubber divided into individual holdings of not less than 6 acres per participant.

(d) Fully assisted new settlement schemes, such as those organised and financed by the Federal Land Development Authority.[5] These schemes provide not only for communications and basic amenities, but for direct management and organisation of the whole group, mechanical preparation of the land where necessary, the supply of planting materials, housing materials, and subsistence (as much as $50 per month) for the first year or two.

There are very great variations in the cost per settler, or per acre of land settled, in terms of contribution from public funds, between the four types of new settlement. It must be emphasized, however, that there is no *necessary* difference in the total investment required for a given settlement by any of the four methods. If a given settlement could be made, by any of the four methods, to the same standards and involving cultiva-

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[4] Dollar amounts throughout this paper are in Straits Currency. $1 Straits currency = approximately 33¢ U.S. Currency or 2s. 4d. English Sterling.

[5] The Federal Land Development Authority is a Corporation set up and financed by government "to promote and assist the investigation, formulation and carrying out of projects for the development and settlement of land in the Federation." (vide p. 1 of "No Need To Be Poor, A Policy Statement" by the Federal Land Development Authority, Federation of Malaya, Kuala Lumpur, December 1956).

tion of the same area of land, the sum total of investment, public and private, would be basically the same in each case. The main difference would lie in the source from which the investment would be derived. In the case of the unassisted settlement, the greater part of the investment would be provided from the private resources of the settlers. In the case of the fully assisted settlement, practically the whole of the investment would initially come from public funds, even though part of it may be in the form of a long term loan to the individual settlers.

In practice, of course, the total investment per settler does vary considerably between individual settlements. This is due to the variation in the size, value and standard of the individual farms and of the amenities made available. The point made here is that such variations are not a *necessary* result of the method whereby the settlement is organised. It is theoretically possible to plan a settlement of any of the four types at a high, or a low, relative level of investment (from all sources) per head.

Of the four types listed above, the first, (unassisted settlement) and the last, (fully assisted settlement) will be considered below, for these are two extremes in terms of public investment, and the contrast between them reveals important principles applicable to all types of settlement.

Nuclear and Peripheral Land Development

Mention has already been made of the two types of requirement necessary in a settlement to induce the mobility of rural labour into the settlement. These are (a) the individual requirements of the settlers such as land, capital, security, tools, subsistence, etc.; and (b) the communal requirements such as communications, markets, and all the social, religious and economic institutions of village life.

This enables a further important distinction to be drawn between two classes of settlement, in which the scale of new investment, and in particular of new public investment, will tend to be substantially different.

In the first class, which may be called *peripheral development*, settlements takes place in and around an existing village or settlement, which is already provided with the basic communal requirements mentioned above. Roads, markets, shopping centres, schools, health facilities, mosques and the like already exist, and provision for the new immigrant population can be made from what is already available, with perhaps some expansion of the facilities here and there. In the case of peripheral development, the call on public funds for the provision of these basic communal requirements is likely to be relatively modest.

In the second class, which may be called *nuclear development*, settlement takes place in a new area, where the basic communal requirements have to be provided *ab initio*. This type of development normally requires

very substantial investment in the provision of these communal requirements over and above the investment needed to meet the individual requirements of the settlers. In the Malayan context, this communal investment will rarely be met by the settlers themselves to a significant degree, but will be a call upon public funds, and to a lesser extent upon the funds of other private investors such as produce dealers, retailers, transport operators and the like.

As nuclear development is very much more expensive, particularly in terms of calls on public funds, than peripheral development, it is clear that the latter is to be preferred as a means of conserving the most scarce factor, capital. However, peripheral development can only take place in a limited area around an existing nucleus, and beyond that limit new nuclei have to be created. In any plan for the large scale relief of population pressure by new agricultural settlement, there will be a place for both classes of settlement. Nevertheless, the maximum effect with the limited funds available will be achieved only if nuclear development is regarded as a forerunner to further peripheral development, and kept to the minimum necessary for that purpose. Moreover, in selecting sites for nuclear development, the prime consideration should be its suitability for the maximum subsequent peripheral development, and otherwise excellent sites, where the scope for further peripheral development is limited by land or other factors, should be rejected.

Fully Assisted Settlement

There are numerous examples of fully assisted settlement in Malaya. The annual report of the Federal Land Development Authority for 1958/9 lists 11 land development schemes in progress. These 11 schemes provide for the settlement of 3,882 families on 39,100 acres of land, mostly for rubber. The estimated cost to completion of these schemes is $22,560,800, or approximately $5,600 per family.[6] This, however, as will be seen, is only part of the total cost.

The majority of these schemes are of a very high standard, and are being implemented successfully. They are designed to produce an income per family, after six or seven years, of from $350 to $400 per month, which is from four to five times what the majority of Malay peasant families earn. They are also very expensive both in terms of total investment and in terms of investment from public funds.

To quote one example, the Solok Menggong Scheme in the Alor Gajah

[6] See *Lembaga Kemajuan Tanah Persekutuan, Penyata dan Kira-kira Tahunan bagi 12 bulan hingga 30.6.59* [Federal Land Development Authority, Annual Report and Accounts for the 12 months to 30.6.59], The Economy Printers Ltd., Kuala Lumpur (available from the Federal Land Development Authority, Kuala Lumpur, Malaya, in English and Malay), p. 32, Table A.

District of Malacca provides for the settlement of 100 families on 1,100 acres of land. Each family will have 6 acres of rubber, 2 of fruit, 2 of padi, and ¼ acre house lot in the central village.[7] The estimated cost is $640,000 of which $400,000 will be provided by the Land Development Authority as a long term loan, to be repaid by the settlers from the produce of their farms in installments commencing in the seventh year, and $240,000 will be derived from the settlers' entitlement under the Rubber Industry (Smallholder New Planting) Scheme already described.

However, these estimates of cost do not include capital or recurrent expenditure by government departments, which cover the provision of access roads, water supplies, electricity (when practicable), schools, teachers' quarters, health clinics, drainage and clearing of rivers, police stations, etc. Although details of this expenditure are not available for any individual scheme, it is clear that in many of the settlements the total of such expenditure will be very substantial.

This type of settlement goes further than is necessary to overcome the immobility of rural labour and induce the settlement and development of new agricultural land. The Federal Land Development Authority receives great numbers of applications for the vacancies in its schemes, and is highly selective in those it accepts. Its declared objective is to create wealth for the farmer, and this it can do, but for restricted numbers. The target for the Authority in the Second Five Year Plan is 12 schemes a year involving the settlement of 4,800 families on about 50,000 acres per annum. If this target is attained it will be a great achievement, but with the rural population expanding at a rate in excess of 100,000 per annum, and little immediate prospect of a significant offtake of rural Malay population into urban industry, it will not be adequate on its own. From the resources that could conceivably be made available for this purpose in most underdeveloped countries faced with a rural population problem, there is no possibility that schemes of the Solok Menggong type could be undertaken on a sufficient scale to deal with the increasing population of the rural areas, let alone to relieve existing overcrowding.[8]

This type of settlement does not throw any useful light on the *minimum* investment necessary to induce mobility. For one thing, it is concerned less with the numbers resettled than with the level of income achieved. Wealth is the primary objective and no attempt is made to economise by

[7] *Ibid.*, p. 43.

[8] According to the Census of Agriculture in 1960, only 10 per cent of all rural farms in the Federation of Malaya are comparable in size with those of the Federal Land Development schemes or larger (i.e. 10 acres or over). The figures show that 59 per cent of all rural farms are less than 4 acres, and 46 per cent are less than 3 acres. See T. B. Wilson, Commissioner for Agriculture Census, Ministry of Agriculture and Co-operatives, "Preliminary Report Number Two, Size of Farms," The Art Printing Works, Kuala Lumpur.

utilising Nurkse's "saving potential concealed in rural underemployment." To obtain the maximum mobility and settlement with the resources likely to be available, a different approach will be necessary. For this purpose a study of unassisted or autonomous mobility will be rewarding, and the facts discovered in a survey of Malay Kampongs on the West Coast of the State of Perak in early 1959 are particularly relevant in this respect.

The Kampong Panchor Area—Background

The Kampong Panchor area comprises a small group of Malay villages on a relatively isolated section of the West Coast of Perak. It covers an area of approximately 15 square miles, on the estuary of the River Jarum Mas. It is approximately 40 miles from Taiping, the nearest market town of any size. Most of the area is within a few miles of the open sea via the Jarum Mas and its tributaries. The area is now inhabited exclusively by Malays.

Originally the area had depended mainly on fishing for its livelihood, but with increasing population, and decreasing catches—due to overfishing of the estuary and nearby coastal waters, and to increasing competition in the fishing grounds—the income from fishing had become quite inadequate. As a result, the people turned increasingly to agriculture, and particularly to the opening up of adjacent swamp jungle for padi.

The success of this move, which had been effected with very little direct assistance from government sources, attracted the attention of land-hungry farmers from the overcrowded padi-growing areas in Kedah and Province Wellesley, 100 to 200 miles to the north, and to a lesser extent from areas of North Perak 60 to 100 miles away. By the time of the 1957 census, the population of the Panchor area was 2,936, of which 604, or nearly 20 per cent, had been born in Kedah or Province Wellesley.

Panchor was an area that had responded in an encouraging manner to a few minor development projects in which the Rural and Industrial Development Authority[9] had taken an interest. These projects included such matters as the establishment of a small Co-operative Society for the breeding of cockles,[10] the introduction of a small agricultural tractor for hire to farmers, and a few other minor improvements. There was some energetic leadership in the area, and an active development committee had been formed.

The Rural and Industrial Development Authority decided to specify

[9] The Rural and Industrial Development Authority is a multi-purpose corporation set up and financed by government for the promotion of social and economic development in the rural areas of Malaya.

[10] The cockles referred to are edible marine bivalve molluscs of the species *Arca Granosa*. Seed cockles are collected from breeding areas and scattered in shallow estuarine waters suited for maximum growth. On maturity they are collected and sold for food.

the area as a "Special Development Area," and in the first quarter of 1959 the Economic and Planning Division of the Authority undertook a survey of the area with the object of assessing the prospects for further planned economic development. The facts discussed below are derived from the results of that survey, and from the comparison of those results with figures for the same villages obtained during the 1957 census.

Evidence of the Mobility of Rural Labour

In designing the survey undertaken in January 1959, care was taken to ensure that certain of the figures in the results would be comparable with the figures of the 1957 census, as the comparison was required to indicate certain aspects of the growth already taking place. To this end, the boundaries of the surveyed area were made to coincide with the boundaries of the group of census sub-areas used in 1957, and a number of the terms and definitions used in the survey questionnaires were modified to facilitate such comparisons.

The period between the Census and the Survey was approximately 19 months, and the results showed that even during that short period, a surprising change had taken place in the size and economic structure of the villages.

The basic figures for comparison were as follows:

	Census June 1957	Survey January 1959
Number of houses	687	822
Number of occupants	2,936	3,329
Number of breadwinners	727	924

These figures indicate an increase of population that is equivalent to a rate of 8½ percent per annum, which means that the rate of immigration into the Panchor area must have been at least 5 percent per annum of the 1957 population during the period, or about 150 people a year. In fact, the actual immigration was certainly greater than these figures indicate, as the survey had to be undertaken during the padi harvest season in North Malaya, which comes earlier than at Panchor, and a number of recent immigrants had returned temporarily to their former homes for the harvest work.

However, even more significant, and a better indication of the actual immigration taking place, are the figures for the number of houses and the number of breadwinners. The number of houses had increased in 19 months by 135, which is equivalent to a rate of 85 houses, or about 12¼ percent, per annum, and the number of breadwinners by 197, which is

equivalent to a rate of 124, or about 17 percent, per annum. These figures indicate that a surprisingly high degree of mobility of rural labour had been induced apparently at a very little cost to public funds, and the numbers involved are significant when compared with the Alor Gajah Land Development Scheme to settle 100 farmers at a cost of about $640,000.[11]

Further light on the remarkable degree of mobility of labour found in these villages is found in the figures of the principal occupations of breadwinners. The figures for the main occupations in the area are shown in Table 1.

TABLE 1. PRINCIPAL OCCUPATION OF BREADWINNERS, PANCHOR AREA, JUNE 1957 AND JANUARY 1959

Occupation	Census, June 1957		Survey, January 1959	
	Number	Percentage Total Breadwinners	Number	Percentage Total Breadwinners
Padi planters	264	36	417	45
Fishermen	247	34	191	21
Teachers, Govt. etc.	35	5	35	4
Woodcutters, etc.	37	5	36	4
Retailers, hawkers	43	6	57	6
Rubber tappers	22	3	22	2½
Coconut pluckers	32	5	19	2
Attap makers	7	1	25	2½
Cockle gatherers	1	—	23	2½

Of the changes indicated, the most significant are the sharp increase in the number and proportion of padi planters, and the sharp decrease in fishermen. This indicates not only that a substantial proportion of the immigrants became padi planters in Panchor, but also that there was considerable mobility of labour between the two industries amongst the existing residents of Panchor. Apart from the major changes in these two industries, the only changes of importance are the decrease in coconut pluckers, and the increases in retailers, attap makers and cockle gatherers. The increase in attap makers is due to the large number of new houses being built, which require attap for roofing and walls. The increase in cockle gatherers was due to the organization of a new cockle breeding association amongst a group of immigrants from a depressed fishing area in the north of Perak.[12]

[11] See p. 767. The size and income potential of the individual farms opened up by the Panchor settlers are, of course, substantially less than those in the Alor Gajah scheme.

[12] The details in the survey results do not cover the reasons for the decrease in coconut pluckers or the increase in retailers.

How Mobility Was Achieved

There is thus proof that factors operating in the Panchor area proved sufficient to overcome the immobility of rural labour on a significant scale, not only between industries within the group of villages itself, but also between Panchor and overpopulated areas up to 200 miles away. This mobility was on a scale comparable to that expected to be achieved by the investment of over $600,000 from public funds in the Alor Gajah Land Development scheme, although in the Panchor case the mobility was very largely spontaneous, and without direct organisation or finance by Government or its agencies. How then was the immobility overcome in this case? What was the order of investment involved? From what sources was the investment derived?

These are questions on which further research is still required. However, sufficient is known to indicate in broad outline the main features of the answers, and to justify the thesis that further detailed research would be fruitful. This is based on a number of individual cases known to the writer through personal contact with the people of this group of villages over a number of years.[13] These cases fall into two distinct groups.

The first, and larger, group comprises immigrants from the overpopulated padi areas of North Perak, Province Wellesley and Kedah. The areas from which these people come are in the main high-yielding, irrigated padi lands and the people have in general been padi farmers for generations. The irrigated lands are thickly populated and the available good padi land has all been taken up for a considerable period. The continuing increase in population in recent times has resulted in more and more people living off the same area of land. Owing to the richness of the land, and to the success of the Department of Agriculture in increasing yields by the introduction of improved strains etc., starvation and hunger are still rare. Seasonal underemployment is very marked, although during the planting season there is a short period of reasonably full employment on many farms, and during the harvest there is a brief shortage of labour that is met by an influx from other areas.

The immigrants that the writer has known from these areas have, in the main, been people who have a right, either by inheritance, or by family connection, to a share in the crop of a rice farm in the North. They work on the home farm during the planting and harvest seasons, and sometimes supplement this by some casual work for other farmers in the peak seasons. In this way they obtain a minimum subsistence for themselves and their families for the whole year, but for most of the year there

[13] The writer served from 1951 to 1957 as State Development Officer, Perak, and was in close contact with this group of villages throughout that period.

is little or no useful employment for them on the home farm, which is then grossly oversupplied with labour. Whilst hunger is rare, the bare subsistence living is below what they regard as a minimum acceptable standard, and as their children increase in number, age and appetite, it is clear that the home farm cannot provide for their increasing needs indefinitely.

This pattern is influenced by the Islamic laws of inheritance, which provide that the estate of a deceased Mohammedan must be divided amongst all the immediate family, including the wives and female children. This means that a farm that was sufficient to support a man and his family at a reasonable standard of living is often divided, on the death of the original owner, into a number of shares, each of which may be inadequate to support the family of the inheritor. Under these circumstances there develops a strong incentive for some of the inheritors to seek land elsewhere, leaving the general operation of the farm to the remaining members of the family, but retaining a right to a reduced share in the proceeds, at least until the others can buy him out, or until he is successfully established elsewhere. This institution, by providing for the sustenance of the prospective emigrant whilst he is getting established elsewhere, greatly facilitates the mobility of rural labour, provided (a) the opportunities for taking up new land become available before overcrowding of the home farm reaches the stage where the individual shares fall below the minimum subsistence level, and (b) it is possible for the emigrant to return to the home farm for the planting and harvest seasons until his new farm is in production. In the latter connection, an important feature in Malaya is that the planting and harvest seasons vary considerably from north to south, and from east to west of the Peninsula.

The pattern of emigration then proceeds roughly as follows. Having located an area to his liking, the prospective emigrant secures a right to some land. There is usually a site for a house, some dry land for miscellaneous crops, and a few acres suitable for wet padi.

With these formalities completed, the man himself moves into the new area temporarily, usually after the home padi harvest. At this stage the children, and often the wife, are left at the home farm, and the man takes with him a supply of rice for his own consumption together with such small resources of cash as he can command for the purchase of materials. He sets about erecting a simple house on the new site, and clearing the land for padi. He may also plant a catch crop that requires little attention, such as tapioca, where opportunity offers. He will continue on this basis, returning home for the padi planting and harvest, and at other times if his work is interrupted by his supplies running out, sickness, etc., until he considers his new land is sufficiently developed to support his family. Then the family moves down permanently, although in the event

of crop failure or other catastrophe, they may still return for periods to the home farm during the first few years until they are firmly established in the new area.

A further factor that facilitates mobility under these conditions is the fact that emigrants tend to move in groups. A single immigrant from one area is relatively rare, and in most cases, at least within a few years, there will be found established in the new area small sub-communities of relatives and neighbours originating from the same village or area. In this way the institutions that contribute so much to the social and economic security of the individual in kampong life are rapidly re-established in the new area.

The second group of immigrants was much smaller, and quite different in many important respects. They comprised destitute members of a depressed fishing community from the Port Weld area, about 50 miles by road from the Panchor area, on the coast. This community had been living in dire poverty, their income from fishing having declined over the years for much the same reasons as had affected the fishermen of Panchor, but more drastically. In addition, there was no available land in the Port Weld area suitable for agricultural expansion.

Eventually, with the agreement of the Panchor Development Committee, an attempt was made to encourage a number of these people to move to Panchor, where State land could be made available for them. This was not an organised settlement scheme, in the sense that the Federal Land Development Authority organises such settlements. However, it was sponsored by Government, and a certain very limited amount of direct assistance was given them to facilitate their move.

These people, unlike the immigrants from the padi areas, had no reserves or resources to meet their subsistence needs whilst establishing themselves in the new area. For this reason the Rural and Industrial Development Authority was asked to assist in providing an early means of earning income for these people, which it was able to do through the organisation and financing of a cockle breeding association among the immigrants. Even so, for several months before the cockle season commenced, the position of these immigrants was so desperate that the Social Welfare Department was called in to assist with the distribution of a certain amount of free rice.

Little more can be said about this special group of Port Weld immigrants, because the writer ceased to have frequent direct contact with the area before the full number of the group had been established at Panchor, and no other records of the progress or success of the move are available. The importance of this group in the present context is that, in contrast to the immigrants from the padi areas who received, and apparently required, no direct Government financial assistance, the immobility of the Port Weld immigrants could not have been overcome without some

direct assistance, however small in comparison with that considered necessary in other Government settlement schemes.

This suggests some very interesting conclusions:

(a) That the obstacles to the mobility of rural labour may be lower amongst groups where underemployment is seasonal rather than chronic, in that Nurkse's "saving potential concealed in rural underemployment" is more readily utilised for investment in the former case;

(b) That where poverty is increasing progressively, there may be a critical point where the stimulus to move afforded by increasing need is suddenly offset by the inadequacy of the resources available for autonomous mobility; and

(c) That even when that critical point has been passed, the ability to move may be restored under certain conditions at a very small cost to Public funds.

It is now possible to consider the first of the questions posed at the beginning of this section: How was the immobility overcome in this case? The answer is clearly that there was in Panchor a largely fortuitous combination of factors that proved favourable to the development of autonomous, or nearly autonomous, mobility of rural labour, and to the utilisation of the peasant's resources for capital formation. Let us now consider the nature of those favourable factors, and whether they are necessarily fortuitous, or whether they can be artificially reproduced in the course of planning.

Factors Favourable to the Development of Autonomous Mobility

The favourable factors fall naturally into two groups. First are the factors affecting the migrant himself, the circumstances of his life before emigration, the resources at his disposal, and social and economic institutions affecting his ability to move. These may be called the *enabling factors.* Second, there are the factors affecting the area to which he emigrates, which determine the suitability of that area to the needs and resources of the migrant. These may be called the *opportunity factors.* This distinction is important because, as will be seen, the degree of mobility induced by any given situation will depend not only upon the strength of the individual factors, but also, and in at least equal degree, upon the extent to which the opportunity factors match, or are appropriate to, the particular set of enabling factors in the situation.

Enabling factors

The enabling factors are numerous, complex, and will vary widely from community to community and from village to village. They involve the effects of racial characteristics, social and religious institutions, just as much as the purely economic conditions of the environment. Space will not admit of an attempt at a detailed analysis of these factors in this

paper, nor indeed is the information available sufficient to make such an analysis possible. All that can be attempted is a brief discussion of some of the more obviously important enabling factors in the case studies of the two groups outlined above.

Incentive is clearly an indispensible enabling factor that will be common to all cases of mobility, though the form which the incentive takes may vary. In the two groups of cases cited above, the incentive was the threat of worsening poverty on the one hand, and the hope of an improved standard of living on the other.

Skills are an important factor. The major group were skilled agriculturalists, and in particular, padi farmers. The minor group were skilled fishermen. The implications of this are obvious where, as in the case of Panchor, the opportunities for expansion lie mainly in the field of agriculture.

Labour, in the sense of labour available for investment or capital formation, is a complex factor. It is not simply the sum of the labour of the settler and his family, but the sum of the labour he can devote to these purposes after providing for the immediate subsistence needs of his family. In the case of the two groups described above there was a very great difference in this respect. Even if it were possible to assume that both groups, on their home ground, had been maintaining a similar level of subsistence and were underemployed to the same extent, this does not by any means mean that the amount of labour available for such investment was the same. This would only be the case where the distance between the old home site and the new settlement is very small. In the cases cited, the distances were considerable and travelling time and expense was an important factor. Consequently the labour available for investment in the new site was very much greater for the major group, whose subsistence income for the year was derived from two relatively short periods of intensive employment, than for the minor group whose subsistence was derived from spasmodic employment on odd days throughout most of the year.

Capital, in the type of settlement here considered, is very largely the end product of a process of capital formation derived from the investment of surplus labour. In this sense it is not an enabling factor, but a result. Similarly, the subsistence supplies upon which the settler supports himself and his family whilst investing his labour are not considered under this head, as they have already been taken into account in the definition of available labour for investment. However, there are a number of other capital items that must be met, and the availability of the necessary resources, in the form of cash savings, credit or materials, is an important enabling factor. In the cases cited above, the amounts required were relatively small, but the availability of these small resources in the major

group, and the inadequacy of the resources in the minor group, made a considerable difference to the opportunity factors required to overcome the immobility of the two groups. The type of capital items considered under this heading include tools, planting materials, such building materials as were not readily obtainable from the jungle, and the like.

Social security, in the sense of some form of institutional safeguard against sickness, crop failure or other catastrophe, is a very important enabling factor. In an underdeveloped country this is most likely to take the form of a social or religious institution of mutual assistance within the family or community unit. Its effectiveness as an enabling factor will depend on a number of circumstances, of which ready and prompt access to assistance in time of need is a variable of considerable importance to the settler. In this connection the maintenance of close family ties in the old home area, as when part of the family remains established on the home farm, greatly facilitates mobility. So also does movement of groups comprising relatives and neighbours from the same area.

Opportunity factors

The opportunity factors are also diverse, and will vary from situation to situation. They fall into two main classes, *natural resources* on the one hand, and *improvements or amenities* on the other.

Natural resources of course include *land*, which is perhaps the most important opportunity factor in an agricultural settlement. It also includes many other factors such as, in the particular case of Panchor, the availability of considerable materials for house building in the jungle nearby, the suitability of the shallow waters of the estuary for cockle breeding, and a series of streams in the potential padi area readily adaptable with minor damming and bunding for irrigation purposes.

Improvements and amenities include communications, major irrigation and drainage works, schools, health services, shopping centres, markets, etc., as well as credit facilities, subsidies, planning, management and other forms of *special assistance* made available by government or other agencies. In the case of Panchor very little in the way of *special assistance* was provided or necessary, whilst the other improvements and amenities were already in existence on an adequate scale.

Conclusions

The planning problem is largely one of economising in the use of capital, so as to achieve the maximum mobility, amongst the particular groups requiring relief, per unit of capital invested. In some cases there may be another limiting factor, in that the maximum mobility may be achieved at a level of investment per settler that is too low to produce an adequate standard of living. In such cases, the objective must be to achieve the

maximum mobility consistent with a satisfactory standard of living for the settlers. However, if the standard is set too high, available resources of land and capital will be wasted in terms of the relief of population pressure achieved.

In the process of economising, the distinction between nuclear and peripheral development is important. Peripheral development is very much more economical, particularly in terms of expenditure from public funds, than nuclear development. For this reason, nuclear development should be kept to the minimum necessary to provide the required scope for peripheral development, and the sites for nuclear development should be selected and evaluated on the basis of their effectiveness as a centre for further peripheral development.

Economising in the use of capital is necessary in total terms, but it is also necessary in terms of the proportion of that capital derived from public funds, whether in the form of expenditure on public works and services, subsidies, or long term loans to settlers. The capital resources of underemployed labour from overpopulated agricultural areas are liable to be small, and the main resource they have available for investment is that portion of their labour potential not used in the production of the minimum subsistence for their families.

In an area where underemployment is rife, but not accompanied by starvation, the amount of such labour available for investment may be considerable. The problem is to provide the maximum opportunity for the investment of that labour in the new land. This problem will be easier where the underemployment is seasonal rather than chronic, and in areas where the level of living of the underemployed labour is still above the minimum subsistence level. There is therefore considerable advantage in relieving the population pressure before it becomes too acute, for once it passes that critical point, Nurkse's "saving potential concealed in rural underemployment" ceases to be readily available for investment, and the cost of inducing mobility will rise sharply.

To achieve maximum effectiveness in the employment of the capital available for this purpose, the factors favourable to the development of autonomous mobility amongst the groups requiring relief should be studied in detail. The situation is governed by the factors affecting the ability of the prospective immigrant to move and to invest his labour. These may be called the enabling factors, and detailed research to discover the nature and degree of these factors for each group should be undertaken in each case as the basis of planning. The maximum economy in terms of mobility per unit of capital invested will then be achieved by designing the factors affecting the new settlement and the assistance to the settlers, described as the opportunity factors, to match the enabling factors and to provide the maximum opportunity for their utilisation.

BELIEFS, VALUES, AND ECONOMIC DEVELOPMENT

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PARTICIPANTS in efforts to promote economic development in the so-called "underdeveloped" countries have noted—often with bafflement and dismay—that progress is thwarted by an apparent unresponsiveness of the people they are trying to help, a phenomenon that is not wholly confined to underdeveloped countries. Powerful beliefs and values regarding the modes of conduct that give men rightful claims to superior status guide their actions in the economic as well as other spheres of life. These need to be better understood.

Traditionalism is the term generally used in denoting the cluster of beliefs and values that functioned as chief guides to problems of social organization and economic endeavor in western society until about the 1600's. Substantially similar beliefs and values still guide thought and practice in most of the so-called underdeveloped countries. When these are laid alongside dominant American beliefs and values, one is struck by opposite attitudes toward economic employments as a proper test of status.

To better understand this fact and its implications, discussion is centered in the following questions: (1) How do traditionalist and modern beliefs differ in the line drawn between economic and noneconomic employments on the one hand, and between work and leisure on the other? (2) How do traditionalist beliefs rank economic and noneconomic employments as ways of demonstrating status deserts—rightful claims to superior standing in one's own eyes and in the eyes of others? It is commonly recognized that, by and large, traditionalist cultures took their start from a belief that prowess is the proper test of rightful claims to superior status. This leads us to ask: (3) What technological conditions underlie the genesis of this belief? (4) What institutional relationships are implicit in the historic prowess test of status deserts? (5) What presuppositions concerning human nature are cornerstones of traditionalist attitudes toward economic employments and master-servant types of institutions?

I. Economic and Noneconomic Employments

Offhand, most people are certain that they know the difference between economic and noneconomic employments. But just how does one test whether a given employment is economic or noneconomic? This question is not an easy one to answer.

[1] The opinions expressed in this article are those of the author and do not necessarily represent the views of the Farm Economics Division, or the U.S. Department of Agriculture.

Certainly, our modern common sense and traditionalist common sense differ sharply on this point. In our highly commercialized culture, the ready answer is that an employment is economic if it is done with pay and noneconomic if done without pay even though exactly the same goods or services are produced in both instances. By this test, a minister's employment, for example, is an economic activity if he receives pay for his sermons and other spiritual services, and his work is productive because it increases the gross national product by an amount equal to the number of dollars he receives for his service. If, however, he delivers these sermons and other spiritual services without pay, his employment is called noneconomic; it adds nothing to the gross national product; therefore, it is unproductive. The whole thing seems ridiculous, but that's the logic of this matter. In the eyes of commercialized common sense, what always stamps any activity as economic or noneconomic is not the kind of good or service it yields but whether its good or service is first exchanged for money and this in turn is traded for different kinds of goods and services.

This kind of common sense would be considered nonsense in traditionalist cultures, where dependence of livelihood on the exchange of goods and services is largely absent since their economy is mainly a subsistence agriculture. To be sure, most traditionalist societies include some businessmen, traders, hired artisans, and wage workers. But their numbers and the scope of their activities are too small to stamp their commercial images into the dominant ways of thought and practice.

In such a society, the common-sense test of whether an employment is economic or noneconomic turns on the kinds of goods and services produced. Economic employments are equated with activities like farming, mining, and manufacture, which provide material subsistence. In contrast, noneconomic employments are equated with activities that produce mainly nonmaterial or "spiritual" goods and services. Into this category fall the priestly, intellectual, artistic, political and military pursuits, as well as sports. In the priestly employments, the objective is not the production of material means of life but the disclosure of the attitudes of the gods and the kind of deeds they require of men. Similarly, in political employments, the objective is the formulation and administration of justice—equitable rules which all must observe for the sake of the general welfare. In military pursuits, the good or service one seeks to produce is the common defense or conquest; in scientific and artistic employments, the objectives are the discovery of new truths and beauteous forms; and in sports, the goal is the infusion of the body with strength, grace, and beauty.

As technical advance at length transformed production for direct use into production for exchange, everyone's livelihood became increasingly dependent on market exchanges of most goods and services, material and

spiritual alike. All goods, whether spiritual or material, thus acquired a common denominator—price tags. As this happened, the older traditionalist belief that the terms "economic" and "noneconomic" referred to physically separate activities, lived on in the modern mind as vigorously as it had in the ancient mind, but the ax used to chop them apart ceased to be the kinds of goods produced and became the receipt or non-receipt of pay.

But neither pay nor the kinds of goods and services produced has any scientific standing as a means of designating the economic and noneconomic nature of employments. For the foundation axiom of economic theory is that men seek to act in ways that will maximize their satisfactions. In line with this presupposition, the term "economic" means simply the "rational" accomplishment of given purposes with the least possible expenditure of limited means: time, energy, personal capacities, and other resources. Thus, any activity is economic to the extent that it is accomplished in this way, irrespective of whether it be done with or without pay, and also irrespective of the kind of goods or service it yields—whether a poem, a prayer, a painting, a pair of shoes, or an ear of corn. By the same token, any activity is noneconomic to the extent that it involves waste of the means for achieving its objective. Thus, every phase of life from the cradle to the grave is economic or noneconomic, depending upon whether it is characterized by a rational or wasteful use of limited means for given purposes. This scientific meaning of the term "economic" permits no physical separation of life into a sphere of economic employments on the one hand, and noneconomic employments on the other. There is no room for such dichotomies in scientific thought, although they flutter around in common-sense discourse like crows in a cornfield.

II. Concepts of Work and Leisure

Common sense uses the same ax for dividing time into work and leisure that it uses for dividing employments into economic and noneconomic activities. Thus commercialized common sense equates work with time spent in employments with pay, and leisure with time spent in activities without pay. If, for example, the minister receives pay for his sermons and other spiritual services, his activity is called work, but if he receives no pay, the same activity is called leisure. Similarly, child care and training is called work if done by a salaried nurse or teacher, but leisure if done by the unpaid parent. In like manner, one and the same expenditure of time and energy in baseball, or any other sport, is called work if the player is paid, but leisure if he is not.

Traditionalist common sense, however, equates work with time spent in the fashioning of physical materials and forces into the material means

of life, and leisure with time spent in other activities. By using pay as the measure of productivity and also as an ax for chopping time into work and leisure, our commercialized common sense can draw no clean-cut distinction between productive and unproductive leisure. All leisure is unproductive, although indirectly it may contribute to productivity in so far as it is used in ways that replenish energies expended in paid employments.

Traditionalist common sense is not burdened with this absurdity. Productive leisure is time spent in creating nonsubsistence or spiritual goods and services. Such leisure includes religious, scientific, artistic, and political employments. In saying that leisure is the foundation of civilized life, Aristotle did not mean idleness, or unproductive leisure, but use of time in the production of social and economic justice, civil order, sculpture, architecture, drama, science, philosophy, and the like.[2]

To all practical intents and purposes, our commercialized common sense equates all productivity with work and unproductivity with leisure. In contrast, traditionalist common sense equates all real productivity with productive leisure. It looks upon work as a curse—an evil suffered only because of the fear of the worse evil of starving if we don't work.

In contrast to either commercial and traditionalist common sense, the modern scientific concept of the economic and noneconomic aspects of any activity precludes any substantive difference between productive leisure and productive work. Productive work is simply the intelligent, methodical accomplishment of given purposes with the least possible expenditure of limited time and other resources, irrespective of whether one's employments be paid or unpaid, or whether the products be material subsistence or spiritual goods and services. But this is also true of productive leisure. Thus, the substantive meaning of productive leisure and productive work alike is the effective unfolding of one's prized interests and capacities into goods and services. When this is not the case, one's employment is drudgery; it is not only boring but a waste of his highest potential, irrespective of whether he is paid or unpaid, or whether he paints pictures or makes mousetraps.

III. The Traditionalist Imperative

Far more striking and of profounder import than the opposition in modern and traditionalist common sense concepts of economic and noneconomic employments, and of work and leisure, is the opposition in their deep-seated beliefs with respect to employments that are deemed to be correct ways of proving that one possesses qualities of mind and char-

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[2] For provocative remarks on the difference between idleness and leisure see Josef Pieper, *Leisure the Basis of Culture*, Faber and Faber, Ltd., 24 Russell Square, London, 1957, pp. 49, 51, 75.

acter which entitle him to the ever higher standing which each of us seeks in his own eyes and in the eyes of others. For the fact is well recognized that traditionalist cultures are anchored in the belief that prima facie evidence of deserts to high standing is exemption from all employments having to do with fashioning the material means of life, and that dependence on such employments is unquestioned proof of deserts to inferior status.

This belief obviously includes the axiom that maximizing happiness and minimizing discomforts lies in limiting work to the amount required to support one's customary mode of living so as to be able to spend the greatest amount of time and energy in noneconomic employments. In this axiom resides the central traditionalist imperative—the feeling that one fails in his responsibility to do all he can to uphold his own high standing and that of his fellows as well unless he limits the expenditure of his time and energy in economic employment to the minimum required to support his customary way of life. Rooted in this belief, reason and conscience can offer no explanation, except greed or miserliness, why anyone should forego leisure for the sake of doing more work than is necessary to support his customary needs.

The widespread prevalence of this traditionalist belief is evidenced on every hand. The following instances are typical. For a professional man in India, for example, to work in his own yard or for his wife to clean her own house is to deserve the disesteem of all classes, high and low alike. Even colonial America was so deeply committed to this traditionalist test of merit that a chief function of dress was to symbolize man's standing in the social hierarchy according to the degree of his exemption from, or dependence on, the so-called economic employments. As Nettles observed, "when adorned with pearl necklace, gold pendant, silver earrings, and gold rings, a lady was not to be mistaken for a woman who worked at menial tasks, nor could her husband or father be ranked as other than a member of the upper class.[3]

In his study of Antigua, a sugarcane-producing island of the West Indies, Rottenburg reported that planters:

> . . . lament their inability to find sufficient workers to take the crop of the fields within the optimum time period and the unwillingness of workers to perform certain tasks at all. Workers who do accept employment . . . refuse to work full work-weeks but prefer to work relatively few days each week.[4]

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[3] Nettles, Curtis P., *The Roots of American Civilization,* Appleton-Century-Crofts, Inc., New York, 1938, p. 308.

[4] Rottenburg, Simon, "Income and Leisure in an Underdeveloped Economy," *J. Political Econ.,* Vol. LX, April 1952, p. 99. Also see Paul A. Baran, "National Economic Planning," in B. F. Haley (ed.), *Survey of Contemporary Economics,* Vol. II, Homewood, Ill., 1952, p. 378. Also Joseph F. Spengler, "Demographic Patterns," in Harold F. Williams and John A. Buttruck (ed.), *Economic Development: Principles and Patterns,* New York, 1954, p. 96.

A report of the Economic Policy Committee of Jamaica speaks thus:

> Many West Indian workers [do] not want to work for wages regularly five or six days a week all the year round. . . . They prefer to have a lower standard of living and more leisure; they are not educated to appreciate a higher standard of living, and would rather take life more easily than add to their material comforts.[5]

The same principle is set forth in Boudin's account of his conversation with a native Indian of a South American village.

> "I like your flute, I will buy it. How much does it cost?"
> "Five solas, señor."
> "That seems like a lot to me; if I buy half a dozen, how much will you charge me?" Of course, I expect to pay less for each flute, but the reply comes at once: "That will be seven solas, señor."
> Slightly puzzled, I continue the experiment. "What if I order a dozen?"
> "In that case, it will be ten solas for each flute, señor."
> "Look here: The more flutes I order, the more profit you will be getting but instead of encouraging me to order more, you are discouraging me."
> The Indian looks at me with an enigmatic and slightly mocking smile as if to say, "These white visitors are certainly strange people."
> "But naturally, señor," he says, "to make one flute is fun; to make six would bore me; to make twelve would simply be unbearable."[6]

In the latter part of the 19th century, Weber observed that in East Germany, farmers often tried to induce workers to speed up the harvest by raising the piece rate. They usually found, however, that this resulted in less work instead of more:

> The worker reacted to the increase not by increasing but by decreasing the amount of his work. . . . The opportunity of earning more was less attractive than that of working less. He did not ask: How much can I earn in a day if I do as much work as possible? but: How much must I work to earn the wage, 2½ Marks, which I earned before and which takes care of my traditional needs?[7]

In traditionalist cultures, the prospect of higher profits tends to be as ineffective an inducement to greater industry on the part of businessmen as higher than customary wages is on the part of workers. Speaking of the early-day German textile industry, Weber observed that:

> The form of organization was in every respect capitalistic; the entrepreneur's activity was of a purely business character; the use of capital, turned over in business, was indispensable; and finally, the objective of the economic process, the bookkeeping, was rational. But it was traditionalistic business, if one con-

[5] Simey, T. S., *Report of Economic Policy Committee of Jamaica*, London, 1948, pp. 133-34, cited by Simon Rottenburg, *op. cit.*, p. 99.

[6] Boudin, Louis, "Traditionality in Economics," *Quarterly Journal of Economics*, Vol. LXVIII, Nov., 1954, pp. 488-89.

[7] Weber, Max, *The Protestant Ethic and the Spirit of Capitalism*, translated by Talcott Parsons, Butler and Tanner Ltd., Fromer and London, 1930, pp. 59-60.

siders the spirit which animated the entrepreneur; the traditional manner of life, the traditional rate of profit, the traditional amount of work, the traditional manner of regulating the relationships with labor, and essentially the traditional circle of customers and the manner of attracting new ones.[8]

In the same vein, Rottenburg concluded his study of traditionalistic attitudes toward economic employments with these words:

A man who has been brought up in a community . . . which attaches prestige to the possession of material goods will not begin to offer less labor until there is a large increase in the price for his service or until the price is very high. On the other hand, a man who lives in a society which values leisure and which attaches no social stigma to living at a close-to-subsistence level will begin to offer less labor when increases occur and when the price is very low . . . In these circumstances, movement between jobs and the number of hours worked or energy exerted at work may be more powerfully affected by the value system of the community than by the price of labor in different trades. Where this is true, the expression of labor supply as a function solely of price gives the economist a dull analytical tool which obscures perception of the really significant relationships.[9]

The key feature of these observations is the relative ineffectiveness of the so-called materialistic income incentive (higher profits or wages) to induce greater productive effort. In attempting to explain this fact, Weber heaved at us what is supposed to be a clincher in his famous saying:

A man does not "by nature" wish to earn more and more money but simply to live as he is accustomed to live and earn as much as is necessary for that purpose.[10]

What Weber overlooked is that the powerful status drive may operate as either an inhibitor or a generator of economic growth, depending on which of many alternative beliefs men may hold concerning appropriate ways of earning high standing. If for any reason, they should take to themselves the belief that contact with economic employments demonstrates deserts to inferior status, we should then expect the status aspiration to become an aversion to doing any work at all, and that, by and large, this aversion would be counteracted by the fear of privation only up to the point where man 'by nature' desires to earn enough "to live as he is accustomed to live" and then to take it easy. This, as we have seen, is what we do find.

But we should expect a very different result if for any reason men should take to themselves the belief that increasing proficiency in any employment one may choose is the proper way of proving that one possesses attributes of mind and character that entitle him to increasingly

[8] *Ibid.*, Weber, Max, p. 67.
[9] *Op. cit.*, Rottenburg, Simon, pp. 96, 100, 101.
[10] *Op. cit.*, Weber, Max, p. 60.

higher status. For, as the desire for such evidence is insatiable, men would feel obligated to earn more and more, not primarily because of 'materialistic' desires for physical ease and comfort, but because of their aversion to inferior status deserts which are associated with relatively low earnings. Thus at virtually any level of living, however low or high, we should expect to find that the insatiable desire for deserts to ever higher standing is a far more dominant aspect of the drive to earn than the mere materialistic concern for physical ease and comfort. This is what we do find—a fact never more clearly discerned by anyone than Adam Smith:

> For what purpose is all the toil and bustle of this world . . . Is it to supply the necessities of nature? The wages of the meanest laborer can supply them. We see that they can afford him food and clothing, the comfort of a house and of a family. If we examine this economy with rigor, we should find that he spends a great part of them upon conveniences, which may be regarded as superfluities, and that upon extraordinary occasions, he can give something even to vanity and distinction. What then is the cause of our aversion to his situation, and why should those who have been educated in the higher ranks of life regard it as worse than death, to be reduced to live, even without labor upon the same simple fare with him, to dwell under the same lowly roof, and to be clothed in the same humble attire? Do they imagine that their stomach is better or their sleep sounder in a palace than in a cottage? The contrary has been so often observed . . . that nobody is ignorant of it. From whence then arises that emulation which runs through all the different ranks of men, and what are the advantages which we propose by the great purpose of human life which we call bettering our condition? To be observed, to be attended to, to be taken notice of with sympathy, complacency and approbation are all the advantages which we can propose to derive from it.[11]

Thus the fact is that we can no more equate the desire to work and earn only "enough to live as one is accustomed to live" with the original nature of man than we can the "desire to work and earn more and more." Contrary to Weber, the first is no less an acquired way of life than the second. Which is acquired evidently turns on whether conditions of living and of making a living lead to the belief that exemption from, or that increasing proficiency in, industrial employments is the correct way of demonstrating possession of capacities that entitle one to an increasingly favorable image of himself in his own eyes and the eyes of others. Historically, the first of these beliefs preceded the second. What conditions of living and of making a living gave rise to it?

IV. Prowess Requirements of Early Farm Technological Advance

The most plausible answer seems to lie in the early forward steps in farm technological advance.

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[11] Smith, Adam, *The Theory of Moral Sentiments*, first publ. in 1759, Part I, sec. III, ch. II.

(1) The first was the invention of the spear, the bow and arrow, and sharp-edged instruments. As gadgets for destroying life, these implements were weapons, but as means of increasing the food supply they were among the most productive farm tools ever invented: they made the hordes of wild game available for human subsistence. It is questionable whether any agricultural invention ever increased farm worker productivity as much as did the bow and arrow.

The belief-forming role of these new implements was immense, as their operation brought into play a great reservoir of hitherto untapped human capacities: massive force, agility, ferocity, cunning, and violent strain. The livelihood of the whole community depended upon persons most endowed with these predatory capacities. This fact generated the steadfast belief in superior prowess as the correct and proper way of demonstrating status deserts—an equivalence between one's capacities and the high standing that each covets. In no other way would the approving voice of mind and conscience permit one to gratify his aspiration for being the kind of person who merited a favorable valuation of himself in his own eyes and the eyes of others. Any effort that did not involve predatory qualities was unworthy of man. Thus it became the "able-bodied man's accredited office in the social economy to kill, to destroy . . . to reduce to subservience those alien forces that assert themselves refractorily;" so much so that in many tribes "the man must not bring home the game which he has killed, but must send his woman to perform that baser office."[12]

The object of prey was not limited to wild life but extended to man as well; so much so that primitive tribes came to guide their status quest by the belief that proficiency in scalping and head hunting was prima facie evidence that one possesses personal qualities that entitled him to high standing in his own eyes, the eyes of others and the gods alike. When Westerners suppressed this test of status deserts among the Tasmanians, for example, without providing a substitute, they plunged the natives into extreme despair over the meaninglessness of life. For they:

> . . . cut the roots of religious life of the natives. They no longer knew how to propitiate their gods. Their religion was undermined . . . They grew apathetic, indifferent to work and the future, and at the same time so proficient in abortion that the tribe was committing suicide by depopulaion.[13]

(2) The gradual domestication of plants and animals marked the transformation of hunting societies into settled agricultural communities. This advance marked a profound change in the significance of prowess. For as

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[12] Veblen, Thorstein, *The Theory of the Leisure Class,* (first publ. 1899), Modern Library, Inc., 1934, pp. 14-15.

[13] DeGrazia, Sebastian, *The Political Community: A Study of Anomie,* Univ. Chicago Press, Chicago, Ill., 1948, p. 48.

long as technological conditions limited man's way of living and of making a living to a hunting mode of life, the belief in increasingly proficient economic behavior and the belief in increasingly superior prowess, as the proper way of earning ever higher status, were identical. Under this circumstance, proficient quest for status was the generator, not the inhibitor, of proficient economic endeavor. Superiors in the power to maim and kill were also superiors in the power to expand the total food supply.

This situation was reversed, however, with the carryover of the belief in prowess test of status from older hunting societies into settled agricultural societies. Under this circumstance, man replaced wild game as the primary object of prey. Hunting graduated from an agricultural employment to a sport—a leisure employment. Losers in the prowess test of merit, as well as their land and livestock, became chattels of the winners. In this way, expenditure of time and energy in producing subsistence goods and services became prima facie evidence that one was so devoid of meritorious capacities that he deserved only servile roles in life. Thus work became irksome not because it was strenuous, but because it became the badge of servility. By the same token exemption from work became gilt-edge proof that one was so gifted with meritorious capacities that he deserved nothing lower than the managerial roles in life. In this way, the deep aversion to inferior standing became a powerful inhibitor of economic growth for thousands of years. Thus, in carrying over the belief in the prowess method of earning status from hunting societies (where it was economically useful) to settled agriculture where it lost this utility, man became a creature who "does not 'by nature' wish to earn more and more money but simply to live as he is accustomed to live and to earn as much as is necessary for that purpose." We know of no traditionalist culture whose basic beliefs and institutions do not trace back to the ancient carryover of the belief in prowess as the proper test of status deserts, from the early hunting stage of technological advance, where it was economically useful, to the settled agricultural stage of technical advance, where it continued to guide the status quest as effectively as ever while stifling economic growth.

V. The Prowess Test of Status Deserts as the Generator of Institutional Beliefs and Values

In addition to rendering the aversion to inferior standing an inhibitor of economic growth, this carryover further generated basic institutional beliefs and values that functioned as key guides to right living and social organization for thousands of years. Four of them are especially relevant here:

(1) The carryover obviously generated profound commitment of mind

and conscience to the master-servant relationship as the right and proper form (model) of social organization. For the prowess test of status deserts distinctly segregates the managerial and labor roles into master and servant classes, often called lords and serfs. The successful in prowess become personifications of divinelike power and wisdom to lay down the rules which all must observe. Failures become personifications of subservient labor power for providing the whole community with necessary subsistence.

This master-servant model arose not merely from mechanical but also from moral necessity—the need of men for a status hierarchy which they can view as giving each his due. For the prowess test of merit confronts rivals with the choice between the heroic death of a proud freeman and the ignoble life of servility. The choice taken turns on the possession or lack of courage. If the weaker have sufficient courage to choose the death of proud freemen, they defeat the efforts of the stronger to reduce them to subservience. If they lack this courage, their just desert is subservience to the stronger.

(2) Commitment to the prowess concept of status deserts further generated profound belief in seizure as the rightful basis of ownership. For under this concept, it is unthinkable that superior industry, rather than seizure, is the proper way of establishing ownership claims to the exclusive use and enjoyment of scarce goods and services.

This prowess form of ownership combines both proprietary and sovereign power in the same skin. As Commons has observed:

> In our Anglo-American political economy, beginning with William the Conqueror in 1066, there was no distinction between sovereignty which is physical power, and property which is economic power. William was both the sole sovereign over his subjects and the sole proprietor of all the land which his tenants needed for their living or riches. His subjects owed to him military services in maintaining his sovereignty and they owed it to him as rent for the lands which they were permitted to use.[14]

A long and painful ripping apart of these two powers from within the same skins marked the rise of the modern Western world. Rise of our Anglo-Saxon political economy involved an epochal series of rips. No one has summarized these more succinctly than Commons:

> . . . beginning with the Magna Carta in 1215, and ending with the Revolution of 1689, the sovereign was ingeniously divided into two personalities, a sovereign and a proprietor. The sovereign now became the legislature, representing the tenants who became landlord and business proprietors. This revolution made the historical sovereign a figurehead, and also made the judiciary independent of the soverign by giving the judges tenure for life or good behavior, thus depriving the sovereign of his former power to control

[14] Commons, John R., *The Economics of Collective Action*, Macmillan Co., New York, 1950, p. 78.

their decisions by removing them at will. Finally, the amendments to the American Constitution made the judiciary superior to both the executive and legislative officials of sovereignty, by the simple device of authorizing citizens to bring suit against officials on the ground of deprivations of life, liberty, or property, without due process of law, to be decided by the judiciary.[15]

But no such extensive transformation of the older seizure form of ownership has occurred in most of the so-called underdeveloped countries, where industry has made few inroads and farming methods for the most part are still those handed down from the mists of history. Throughout these vast areas, most of the world's population are still farmers, living under feudal or semi-feudal systems of land tenure generated in the long ago by primitive belief in and practice of prowess as the proper way of achieving meritorious distinction.[16]

(3) In addition to generating the master-servant relationships and feudal tenure as the proper political and economic model of social organization, the ancient belief in, and practice of, the prowess test of status deserts necessarily induced a self-sufficiency concept of freedom, which is incompatible with dependence on market exchange. For, within the master-servant relationship, the freeman can be envisioned only as one who has absolute control over all personal services and other resources necessary to meet all his needs. To the feudal lords, for example, it was self contradictory to think of men as free and at the same time dependent for their livelihood upon a market exchange between producers and consumers. No one has expressed this self-sufficiency concept of freedom more truly than did Jefferson in his saying that commerce involves dependence on "the caprice of customers," which "begets subservience and venality," which in turn "suffocates the germ of virtue" and therefore renders men "the fit tool for the designs of ambition."[17]

(4) The historic prowess test of status deserts necessarily generated belief in the superiority of landed proprietors with respect to responsible citizenship—the stalwart spirit of personal independence that brooks no interference with self mastery. For, as previously explained, as plants and animals became domesticated, man shifted the ancient hunter's prowess test of merit from wild game to fellowman and his possessions as the most profitable object of prey. In this way, landed proprietorship over the holdings of the subjugated were deemed the legitimate reward of strong, high-spirited men who earned their free status in mortal combat. Landed proprietorship was gradually substituted for the sword as

[15] *Ibid.*

[16] For an informative account of the way this principle applies to many Latin American countries see Mallory, Lester D., *Bulletin*, U.S. Dept. of State, Vol. XLIII, No. 118, Nov. 1960, p. 819; Childs, Marquis, "Time Ticks Away in Latin America," *Washington Post*, Mar. 17, 1961, ed. page.

[17] *Notes on State of Virginia*, 1782, Query XIX.

the evidential symbol of a passionate devotion to free status that prefers death to servility, which is the sum and substance of solid citizenry. This substitution of symbols survives in such sayings as "farmers are the salt of the earth," "the balance wheel of society," and "the backbone of democracy." More important, without their unquestioned confidence in the validity of these substitute symbols, our forefathers could scarecly have laid the foundations of democratic America. Jefferson typified them when, with one eye to agriculture as the incubator of the spirit of liberty and responsible citizenship, he declared:

> Those who labor in the earth are the chosen people of God . . . whose breasts He has made his peculiar deposit for substantial and genuine virtue. It is the focus in which He keeps alive that sacred fire, which otherwise might escape from the face of the earth.[18]

Then, with his other eye to commerce as the incubator of "subservience and venality" through enforcing dependence on the "caprice of customers," he declared:

> . . . generally speaking, the proportion which the aggregate of other classes of citizens bears in any state to that of its husbandmen, is the proportion of its unsound to its healthy parts, and is a good enough barometer whereby to measure its degree of corruption. . . . The mobs of the great cities add just so much to the support of pure government, as do sores to the strength of the human body.[19]

VI. Traditionalist Presuppositions Concerning Human Nature

While master-servant ways of life (institutions) were first generated by the primitive belief in and practice of prowess as the appropriate way of earning high standing, more powerful supports were soon developed from presuppositions concerning human nature. This fact is readily illustrated through two such presuppositions that were worked out by the ancient Greeks.

The first presupposition is that all human interests fall into a hierarchy of lower and higher wants with respect to intrinsic worth. The general term for the lower wants is the *appetitive* self, as their common denominator is desire for material satisfactions:[20] food, drink, clothing, shelter and the like. These lower wants fall into two main subclasses: necessary and unnecessary. Necessary appetites are the ones whose gratification is both beneficial to bodily health and indispensable to the support of life;[21] and unnecessary ones are those whose gratification may be foregone without injury to physical fitness and effective performance of one's

[18] *Ibid.*
[19] *Ibid.*
[20] Plato, *Republic,* translation by John Llewlyn Davies and David James Vaughn, Macmillan and Co., London, 1929, p. 143.
[21] *Ibid.*, p. 289.

social role (or roles) in life. The unnecessary wants also fall into two subclasses: those which are relatively harmless if gratified in moderation, and those which constitute the "wild beast in our nature."[22]

The general term for the higher wants is the *rational* self, as their common denominator is the desire for nonmaterial satisfactions.[23] Satisfying objects of the higher self include *logical patterns,* which gratify the thirst for the "nature of things" as revealed in their definitions and necessary connections; *beauteous forms,* which fulfill aesthetic hungers; and *virtues, especially justice,* which gratify the aspiration for the system of privileges and responsibilities that give each his due—a social role in life whose skill requirements are equivalent to his creative, serviceable capacities. For each to have such a role is justice.

The second presupposition is that men divide into different character types or classes, depending upon the extent to which they are guided by the demands of the higher or lower self. For example, the highest type of character is called the aristocratic man. This term derives from two words: *aristos* meaning best or noblest, and *kratein,* meaning to manage, rule, or govern. Thus the aristocratic type of character denotes the relative few in whom the higher self is completely lord and master of the lower wants, limiting their gratification to the amount required for customary ease and comfort so as to devote the greatest amount of time and energy possible to fulfilling the higher wants.

At a lower remove is the businesslike character whom the Greeks called the "oligarchical man," meaning the type of person who gratifies only his relatively few "necessary wants" so as to be able to devote the greatest possible amount of his time, energy, and savings to accumulation of wealth, unlimited by any conceivable level of living. Under the higher-lower self formula of human interests, no reason for such unremitting thrift and industry is conceivable except miserly greed. Accordingly, Plato scathed the businesslike man as a "penurious, laborious character . . . a shabby fellow who saves something out of everything;" reduces reason to a calculating machine for figuring out ways "by which lesser sums may be converted into larger ones;" perverts the love of honor and fame "into the worship and admiration of riches and rich men;" and allows himself no ambition except "wealth accumulation and the means of acquiring it."[24] Nonetheless, the business type of character is governed by the higher self to some extent as he asserts mastery over his many expensive but unnecessary appetites.

However, according to traditionalist presuppositions, even this virtue

[22] *Ibid.,* pp. 305-6.
[23] *Ibid.,* pp. 143-4, 149, 187-196.
[24] Plato, "Republic," *The Works of Plato,* Jowett translation, Tudor Publishing Co., New York, pp. 319-322.

disappears in the "democratic man," which is the Greek term for the rank-and-file type of person in whom the higher self is so weak that he regards all his wants as having equal claims upon him, saying that each of them is the equal of any other with respect to intrinsic worth. Thus in the traditionalist view the democratic character is highly unstable, gratifying whichever passion strikes him with greatest force at the moment:

> If anyone says to him that some pleasures are the satisfaction of good and noble desires, and others of evil desires . . . he shakes his head and says that they are all alike, and that one is as good as another." Thus, "he lives from day to day indulging the appetite of the hour: sometimes he is lapped in drink and the strains of the flute; then he becomes a water-drinker, and tries to get thin; then he takes a turn at gymnastics; sometimes idling and neglecting everything, then once more living the life of a philosopher; often he is busy with politics, and starts to his feet and says and does whatever comes into his head; and if he is emulous of anyone who is a warrior, off he is in that direction, or of men of business, once more in that. His life has neither law nor order: and this distracted existence he terms joy and bliss and freedom: and so he goes on . . . He is all liberty and equality.[25]

But the fact remains that in believing that all his wants are of equal worth, the "democratic man" prevents enslavement of himself to his most destructive appetites—"the wild beast" in his nature. Accordingly, the lowest type of character is "the tyrannical man," meaning the type of person in whom all the rational capacities of the higher self have become enslaved to the carnal appetites of the lower self. With these enthroned as his lord and master:

> . . . he breaks out in a frenzy, and if he finds in himself any opinions or appetites such as are deemed good, and there is in him any sense of shame remaining, to these better principles he puts an end, and casts them forth until he has purged away temperance and brought in madness to the full.[26]

VII. Political Implications

These presuppositions concerning human nature bind the mind and conscience of men to master-servant political models as firmly as prowess binds their bodies into the higher and lower nitches. Four observations bear out this point:

(1) The presuppositions generate alternative conceptual political models. For, as the higher and lower aspects of our nature may combine into alternative types of persons (depending on which aspect becomes master of the whole man), so these natural types of men may combine into various political hierarchies, depending on which class is invested with complete managerial control over the others. We may have an *aristocratic (elite) model* if we put complete managerial power in the

[25] *Ibid.*, pp. 332-3.
[26] *Ibid.*, pp. 348-9.

gifted few who are governed by the higher self's knowledge of and desire for an impartial justice; a *business model* if we vest complete power in a relative few who are so dominated by acquisitive greeds that they gratify only their necessary wants so as to maximize their material possessions; a *democratic model* if we put complete power in the 'many' who are governed by whichever turbulent passion may seize them from moment to moment; or we may have a *tyrannical model* if we allow total power to fall into the hands of the relative few who are habitually enslaved by the basest lusts of the lower self. Thus, the central policy consideration posed by traditionalist political theory is simply a question of which master-servant model of social organization represents the wisest choice.

(2) As it is absurd for the inferior to manage the superior, the best possible choice is the elite model, and the worst possible choice is the tyrannical model, and the next worst is the democratic model.

(3) In line with the principle of natural inequality, some are so deficient in managerial capacity that their own best interests and the public interest alike require them to be the bond servants of their superiors. "By nature," these incompetents are slaves or serfs just as the more gifted are nature's freemen. In Aristotle's blunt words:

> . . . from the hour of birth some are marked out for subjection, others for rule . . . For he who has enough of the rational principle to recognize sensible rules but not enough to formulate them, is a slave by nature.[27]

To be sure, the line drawn between freemen and slaves or serfs by the prowess test of status deserts does not coincide with the line drawn by the higher-lower self formula of human action. For this reason, we:

> . . . detest the notion that because one man has the power of doing violence and is superior in brute strength, another should be his slave and subject.[28]

(4) In this way the formula enabled, and still enables, traditionalists to revolt against "irrational" master-servant models that invert nature's true hierarchy of bond and free. However, the larger fact remains that the formula binds the mind and conscience of men to servile institutions as such. Furthermore, it is well recognized that any class has no difficulty in deluding itself with the conviction that its own particular policy views are identical with what amounts to a Divine perspective of the general interest, and in this conviction feel duty-bound to overpower its rivals in order to establish an impartial justice for all classes. So, while the invention of the higher-lower self formula of human nature was, and still is a great intellectual achievement, the question remains if its historic func-

[27] Aristotle, *Politics*, ch. 5.
[28] *Ibid.*, ch. 6.

tion is not simply that of enabling predatory power and privilege more easily to wrap about themselves the robes of righteousness and refuse to be ashamed. More significantly, has any theory of the nature of man and society, traditionalist or otherwise, ever been formulated which the human animal is not able to use as a high-minded concealment of his predatory attitudes from himself and others?

VIII. Economic Implications

In three main ways, the higher-lower self formula of human action undergirds and perpetuates the same economic attitudes and institutions that were originally generated by the primitive belief in prowess as the proper test of deserts to superior status.

(1) It calls for precisely the same division of life activities into economic and noneconomic employments. In both instances, economic employments are those that supply the whole community with material goods and services, whereas noneconomic employments are the activities that supply it with nonmaterial or spiritual goods and services, principally of the kinds already cited. Again, in both cases, work is equated with time and effort spent in economic employments, and leisure with time and effort spent in noneconomic employments.

(2) It generates commitment of mind and conscience to the same traditionalist imperative that was originally generated by the primitive belief in superior prowess as the proper test of status deserts. For in both cases, dependence on economic employments (work) is deemed sure proof of deserts to inferior standing and exemption from such employments (leisure) is viewed as proof of rightful claims to highest standing. The two situations differ only in the justifying reasons for these identical beliefs. Under the older, prowess test of superior standing, the servility of work arises from the belief that economic employments are the just deserts of those who are without sufficient courage to prefer the death of proud freemen to subjugation by the stronger. Under the sophisticated higher-lower self formula, those deserving exemption from economic employments are the relative few in whom the nobler interests of higher self habitually have the upper hand over the materialistic wants of the lower self. The reverse is true of the underlying population who therefore deserve to be saddled with the work of the world.

(3) In generating this belief, the higher-lower self formula of human nature undergirds and perpetuates the same exploitative ownership institutions that were originally generated by the ancient belief in prowess as the proper way of establishing legal rights to the exclusive use and enjoyment of land and other production services. For, when encumbered by the conviction that exemption from industry is sure evidence of

deserts to highest positions, mind and conscience see little or no reason for upsetting feudal or semifeudal institutions except the ignoble one of rewarding the greeds of the "have-nots" by robbing the "haves" of their opportunity and duty to fulfill nobler interests of the higher self and hold in check the turbulence and greed of the lower classes.

IX. Summary and Conclusion

The central theme of this analysis has been that the dominant striving of people in all cultures is the aspiration to earn an increasingly favorable image (valuation) of themselves in their own eyes and the eyes of others. Whether or not this striving works as an inhibitor or a generator of economic growth turns on beliefs concerning ways of living and of making a living that are taken as prima facie evidence that one possesses capacities which entitle him to the increasingly higher standing which each covets. This status aspiration functions as a powerful inhibitor of economic growth if it is guided by the belief that dependence on economic employments is indisputable evidence that one lacks the capacities of mind and character that entitle him to the higher positions. But the same aspiration becomes a generator of unlimited economic growth if it is guided by the belief that proficiency in economic as well as noneconomic employments is the appropriate way of earning an ever higher valuation of himself in his own eyes and in the eyes of others.

The key step in the rise of our own economically dynamic Western society was a revolutionary shift from the first to the second of these beliefs—the belief that no amount of riches can ever exempt one from the responsibility to be as proficient as possible in any employment which he believes best expresses his productive potential. Once this shift in beliefs was accomplished, economic incentives became effective inducements to increasingly productive effort over and above the limits imposed by any conceivable level of customary wants. May not the same principle apply to the vast areas of the globe that still share the same traditionalist beliefs and values with respect to the economic employments and master-servant types of institutions which Western society shared prior to the 16th century? If so, the central question is: How may this revolutionary change in traditionalist beliefs and values be facilitated?

A DYNAMIC QUARTERLY MODEL OF THE BEEF AND PORK ECONOMY*

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A NUMBER of people have used annual time series data to analyze demand for beef and pork. Less empirical work has been done on the determinants of their marketing margins or of meat inventories. Quarterly analysis of demand and of the marketing system for these two products is apt to be fruitful since intra-year seasonal variations in production, margins and prices may be just as great as inter-year variations in production and average prices, especially for pork. Meat packers and chain stores need short-term predictions as a basis for their pricing and inventory decisions. Agricultural price outlook workers are called upon to make predictions of farm prices for periods of less than a year. Quarterly models of the livestock marketing sector can be used by each of these groups.

This paper reports the results of a study of the beef and pork marketing sector of the economy. Eight equations were estimated using quarterly time series data: (a) two consumer demand equations, (b) two meat inventory equations, (c) two farm-to-wholesale marketing margin equations and (d) two wholesale-to-retail marketing margin equations.[1]

Estimation Procedure

Single equation methods are used to estimate the equations. For our present purposes we consider the quantity supplied by farmers to be exogenous. Fox has argued that yearly farm production is largely predetermined and most of his arguments hold with increased force for the shorter period of a quarter.[2]

The statistical results presented below were obtained by a method of estimation which permits autocorrelation in the error term. Three reasons have been advanced to explain the presence of autocorrelated errors:[3]

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[1] A more detailed description of the models presented in this paper is given in "A Non-Static Model of the Beef and Pork Economy," unpub. Ph.D. thesis, by Wayne A. Fuller, Iowa State Univ., 1959.

[2] Karl A. Fox, *The Analysis of Demand for Farm Products,* U.S. Dept. Agr. Tech. Bul. 1081, 1953, pp. 30-33.

[3] D. Cochran and G. H. Orcutt, "Application of Least Squares Regression to Relationships Containing Autocorrelated Error Terms," *J. Amer. Stat. Assoc.,* 44:36-61, 1949.

(1) Incorrect specification of the mathematical form of the relationship, e.g. linear rather than quadratic.
(2) Omission of relevant variables.
(3) Measurement errors.

The last will lead to autocorrelated shocks if the measurement errors have a systematic but variable component. Omission of relevant variables is likely to lead to autocorrelated shocks since some of the excluded variables will commonly be economic variables which exhibit autocorrelation similar to that possessed by the included variables. Likewise, errors arising from the omission of serially independent variables may give rise to serially correlated effects. Thus (serially independent) variations in rainfall and snowfall can result in serially correlated variations in range conditions, since current range conditions are affected by current and past rainfall and snowfall.[4]

The intimate relationship between autocorrelated errors and estimates obtained for models containing lagged dependent variables makes it desirable to use an estimation procedure which permits autocorrelated disturbances. Suppose a true model is

$$y_t = ax_t + by_{t-1} + \mu_t \qquad -1 < b < 1 \tag{1}$$

$$\mu_t = \beta\mu_{t-1} + e_t \qquad -1 < \beta < 1 \tag{2}$$

where the errors, e_t, are assumed to be non-autocorrelated.

Let r^2 be the simple coefficient of determination between x_t and y_{t-1}. Suppose we estimate

$$y_t = ax_t + by_{t-1} + w_t \tag{3}$$

by ordinary least squares. Then

$$\text{plim } \hat{a} = a + \frac{r^2\beta E\mu_t^2}{(1 - r^2)Ex_t y_{t-1}} \tag{4a}$$

$$\text{plim } \hat{b} = b + \frac{\beta E\mu_t^2}{(1 - r^2)(1 - \beta b)Ey_t^2} \tag{4b}$$

where plim $\hat{a}$ denotes the probability limit of the estimate of a. The second term on the right side of (4a) and (4b) is the large sample bias in the estimates of a and b. Note how the bias depends on the value of β, i.e., on the autocorrelation properties of the residuals. If $\beta = 0$, the estimates are unbiased in large samples. In practice β will often be positive. In this case the bias in $\hat{b}$ will be positive, plim $\hat{b} > b$; the bias in $\hat{a}$ will be positive or negative as $E\,x_t\,y_{t-1}$ is positive or negative.[5]

[4] Richard Stone, *The Measurement of Consumers' Expenditure and Behavior in the United Kingdom, 1920-38*, Cambridge: Cambridge Univ. Press, 1954, p. 284.

[5] These expresions were originally derived in a slightly different version in Fuller,

Several of the behavioral equations presented herein contain lagged dependent variables. Because of the relation between the estimates in such equations and the properties of the residuals, β was estimated with the other coefficients. That is, it was assumed that the residuals followed a pattern like (2). It is possible that the true serial correlation properties are more complicated than this. Certainly the assumption (2) is substantially more general than the assumption that the residuals are serially independent.

The estimation procedure used is that discussed by Fuller and Martin.[6] The procedure is an iterative one and approximately twice as many variables enter the computations as are contained in the original specification. For example, if the model is specified by (1) the equation

$$y_t = ax_t - \beta a x_{t-1} + (b + \beta) y_{t-1} - b\beta y_{t-2}$$

is estimated.

The use of quarterly data requires some adjustment for possible seasonal effects. Demand for beef and pork is believed to vary seasonally and seasonal variations in production may result in seasonal variation in stock and margin behavior. An additive quarter effect may be introduced into the analysis by including three dummy variables in each of the equations. Further, the evidence that the demand for beef and pork has undergone autonomous trends leads to the inclusion of time as an explicit variable. Thus the presence of trend and seasonal effects leads to the addition of four variables to each equation. To reduce the computational task associated with the iterative estimation and to reduce the problems arising from intercorrelations among independent variables, the following procedure was adopted. All variables were regressed on time and seasonal variables:

$$\hat{X}_t = b_0 + b_1 D_{1t} + b_2 D_{2t} + b_3 D_{3t} + b_4 T_t \tag{5}$$

where T is a linear time variable with the first quarter of 1949 equal to zero, and the D_i are orthogonal seasonal variables having the following values:

Quarter	D_1	D_2	D_3
1	−1	0	1
2	−1	0	−1
3	1	−1	0
4	1	1	0

Deviations from regression, $X_t - \hat{X}_t = x_t$ were computed and used in the final estimation.

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op. cit. Zvi Griliches has derived similar results in "A Note on Serial Correlation Bias in Estimates of Distributed Lags," *Econometrica*, 29: 65-73, 1961.

[6] W. A. Fuller and J. E. Martin, "The Effects of Autocorrelated Errors on the Statistical Estimation of Distributed Lag Models," *J. Farm Econ.*, 43:71-82, 1961.

The use of these deviations, x_t, is equivalent to using X_t and including in the regression the variables T, D_1, D_2 and D_3.[7] The use of the deviations is also equivalent to measuring the variables as deviations from the respective quarterly means (rather than the overall means), regressing these deviations on time, and using the deviations from this regression in estimation.

The regressions (5) are presented in the appendix. By substituting these expressions into the equations of the tables one may obtain an equation in the original X_t, and D and T.

The R^2 values presented in Tables 1 to 4 are computed on the basis of the deviations x_t. They are partial determination measures; they measure the proportion of variation not explained by time and seasonal variables which is explained by the other variables. Just as the intercept values may differ by quarter so also may the slopes. In investigating this possibility the following procedure was followed. All equations were first fitted under the assumption that the slopes were the same for all quarters. Residuals from these equations were then plotted against important explanatory variables. If this plotting indicated inter-quarter variations in slope, variables were added to the equations to allow for such differences and the augmented equations then estimated.

All equations were fitted to the data for the 43-quarter period starting with the third quarter of 1949 and ending with the first quarter of 1960.

Consumer Demand

One might specify the static demand equation for pork as

$$(6) \qquad {}_EC_{Pt} = b_0 + b_1P_{Pt} + b_2C_{Bt} + b_3Y_t$$

and specify the following relation between actual demand and equilibrium demand[8]

$$(7) \qquad C_{Pt} - C_{Pt-1} = \alpha({}_EC_{Pt} - C_{Pt-1})$$

where

Y_t = current deflated per capita disposable income (in hundreds of dollars) seasonally adjusted,

C_t = current per capita consumption in pounds per quarter-year,

${}_EC_t$ = current equilibrium level per capita demand,

P_t = current deflated retail price in dollars per 100 pounds carcass weight,

[7] For example see Gerhard Tintner, *Econometrics,* New York: Wiley, 1952, p. 301 ff.

[8] Marc Nerlove, *Distributed Lags and Demand Analysis for Agricultural and Other Commodities,* U.S. Dept. Agr. Handbook 141, 1958, esp. pp. 14-20. J. R. N. Stone and D. A. Rowe, "Dynamic Demand Functions: Some Econometric Results," *The Econ. Jour.* 68:256-70, 1958.

TABLE 1. STATISTICS FROM ESTIMATION OF CONSUMER DEMAND EQUATIONS

Dependent variable	C_{Bt}	C_{Pt}	Y_t	${}_1C_{Pt}{}^2$	C_{0t}	C_{Pt-1}	C_{Bt-1}	β	R^2
P_{Bt}	−2.90	− .24	−.26		−.29		−.83	.53	.952
	(.43)	(.35)	(1.31)		(.10)		(.36)	(.17)	
P_{Pt}	− .63	−2.97	−.30	.22		−.38		.67	.909
	(.32)	(.36)	(1.28)	(.055)		(.34)		(.14)	

and the additional subscripts P and B are used to denote pork and beef, respectively.

The subscript t-1 indicates the value of the variable for the preceding quarter. The consumers' price index (1947-49 = 100) is used as the deflator throughout the study.

Substituting equation (6) into equation (7) yields

$$(8) \qquad C_{Pt} = \alpha b_0 + \alpha b_1 P_{Pt} + \alpha b_2 C_{Bt} + \alpha b_3 Y_t + (1 - \alpha) C_{Pt-1}$$

Since the pioneering paper by Working on identification, agricultural economists have commonly stated price as the dependent variable when using least squares to estimate demand functions.[9] The justification is that consumption of agricultural products can be treated as predetermined whereas price cannot be so treated.[10]

Solving (8) for price one obtains

$$(9) \qquad P_{Pt} = -\frac{b_0}{b_1} + \frac{1}{\alpha b_1} C_{Pt} - \frac{b_2}{b_1} C_{Bt} - \frac{b_3}{b_1} Y_t - \frac{1 - \alpha}{\alpha b_1} C_{Pt-1}$$

Table 1 presents statistics obtained from the estimation of equations of type (9) for beef and pork.

Plotting of the original beef and pork data led to the addition of a variable to each of the demand equations. In the case of pork, curvilinearity of the regression of price on quantity was indicated and the variable[11]

$${}_1C_{Pt}{}^2 = (C_{Pt} - 16.47)^2$$

was therefore included in the regression. In the case of beef, during the last three quarters of 1951, price ceilings were in effect and prices were at the ceiling levels. To take account of the effect of ceilings the follow-

[9] Elmer J. Working, "What Do Statistical Demand Curves Show?" *Quar. Jour. Econ.*, 41:212-35, 1927.

[10] Fox, *op. cit.*

[11] The number 16.47 is the mean consumption for a shorter period employed in previous work. One can decode the equation of Table 1 by noting that ${}_1C_{Pt}{}^2 = C_{Pt}{}^2 - 32.94\ C_{Pt} + (16.47)^2$. Thus in decoded form the coefficient for C_{Pt} becomes $-2.97 + 0.22\ (-32.94) = -10.22$ and the coefficient for $C_{Pt}{}^2$ remains 0.22.

ing variable was included in the beef regression:

$$C_{0t} = C_{Bt} \text{ during second, third and fourth quarters of 1951}$$
$$= 0 \text{ otherwise.}$$

This variable permits a shift in the price equation during these three quarters and assumes that the shift in any quarter is proportional to consumption during that quarter.

In both equations the quantity of that meat is the most important explanatory variable. While the coefficients for the quantity of the competing meat are of the expected sign the coefficients are of moderate size relative to their standard errors. In both equations the coefficient for income is negative but both are very small relative to their standard errors. The small variability in income (once the time trend has been removed) apparently prohibits the achievement of precision in the estimation of the income coefficient.

In the pork equation the coefficient for lagged quantity is about equal to its standard error, but in the beef equation the coefficient exceeds twice its standard error. In both equations the coefficients are negative, indicating that the long-run price flexibility is greater than the short-run.

Such a result is contrary to the conclusions of most arguments on the behavior of demand elasticity through time. In view of the difficulties associated with the estimation of lag models one may choose to discount the results. However, such results need not be considered unreasonable. In the consumption of an article such as pork or beef known to be subject to recurring price cycles the enlightened consumer may well overadjust. That is, if the present price of beef is low relative to other prices, but one believes the price will shortly rise, one may consume a larger quantity of beef than if the present price ratios were expected to hold indefinitely.

The computed price flexibilities at the means and their approximate standard errors are

Beef ($\overline{P} = 53.81$, $\overline{C} = 19.1$)	short run	1.03(.12)
	long run	1.32(.15)
Pork ($\overline{P} = 52.09$, $\overline{C} = 16.9$)	short run	.90(.11)
	long run	1.02(.13)

The estimates for β indicate the presence of significant autocorrelation in the errors of both equations. In equations fitted under the assumption $\beta = 0$, the values of the Durbin-Watson d were inconclusive.

Wholesale-to-Retail Margins

It would be possible to describe the behavior of retailers by specifying a retailer's demand curve and a retailer's supply curve. However, meat is

a perishable commodity and is held for a short time by retailers. Thus, unless the period studied is very short the quantity demanded is identical with the quantity supplied. It is, therefore, possible to replace the demand and supply equations by a reduced equation containing the margin between the demand (wholesale) price and the supply (retail) price.

The following model is proposed for the wholesale-to-retail margin for beef:

$$(10) \qquad {}_{E}M_{Bt} = a_1 W_t + a_2 p_{Bt}$$

$$(11) \qquad M_{Bt} - M_{Bt-1} = \alpha_0({}_{E}M_{Bt} - M_{Bt-1}) + \alpha_1 \triangle p_{Bt} + \alpha_2 \triangle p_{Pt}$$

M_t = deflated wholesale-to-retail marketing margin during period t in dollars per 100 pounds carcass weight,

${}_{E}M_t$ = equilibrium level of wholesale-to-retail marketing margin during period t,

p_t = current period deflated average wholesale price in dollars per 100 pounds carcass weight,

W_t = current deflated wage rate of employees in food stores.

The symbol $\triangle$ denotes the first difference. Thus, $\triangle p_{Bt} = p_{Bt} - p_{Bt-1}$. The constant term is omitted from the equation and from many of the equations which follow to simplify the presentation.

The following considerations were relevant in the construction of the model. The margin is, in a sense, the "price" of retailers' services. Of the costs associated with this service, labor is the most important, accounting for approximately two thirds of all cost in retailing.[12] Since retailers are known to practice "average cost pricing" on some commodities, the wholesale price is included in (10) on the possibility that the percentage markup is a part of meat pricing.

The observed tendency of retail prices to lag behind changes in wholesale prices[13] led to the inclusion of the change in wholesale price in the adjustment equation (11). On the assumption that substitutability in consumption would lead to interdependency in retail price movements, the change in wholesale price of the competing commodity was also included in the adjustment equation.

Substituting the equilibrium margin from (10) into (11),

$$(12) \qquad M_{Bt} = \alpha_0 a_1 W_t + \alpha_0 a_2 p_{Bt} + \alpha_1 \triangle p_{Bt} + \alpha_2 \triangle p_{Pt} + (1 - \alpha_0) M_{Bt-1}$$

Selected statistics obtained in the estimation of the margin equations for beef and pork are given in Table 2.

[12] U.S. Dept. Agr., *Farm-Retail Spreads for Food Products*, Misc. Publ. 741, Nov. 1957, p. 14.

[13] U.S. Dept. Agr., *Pork Marketing Margins and Costs*, Misc. Publ. 711, April 1956, p. 18.

In both equations the change in the own wholesale price exerted a significant negative effect upon the margin, whereas the change in the wholesale price of the competing commodity exerted a positive effect on the margin. Thus there appears to be a lag in the response of retail prices to wholesale price changes.

Examination of scatter diagrams led to the conclusion that beef margins reacted to price changes differently during the first half of the year than during the second half.

The variable $\triangle p'_{Bt}$ included in the beef equation is defined as follows:

$$\Delta p'_{Bt} = \Delta p_{Bt} \text{ during the first and second quarters,}$$
$$= -\Delta p_{Bt} \text{ during the third and fourth quarters.}$$

Thus the coefficient for $\triangle p_{Bt}$ becomes $-.31 + .21 = -.10$ for the first and second quarters and $-.31 \ -.21 = -.52$ for the third and fourth quarters. Retailers apparently absorb about one half of the wholesale

TABLE 2. STATISTICS FROM ESTIMATION OF WHOLESALE-TO-RETAIL MARGIN EQUATIONS

Dependent variable	Δp_{Bt}	Δp_{Pt}	p_{Bt}	p_{Pt}	W_t	$M_{B_{t-1}}$	$M_{P_{t-1}}$	$\Delta p'_{Bt-1}$	β	R^2
M_{Bt}	−.31 (.045)	.16 (.035)	.12 (.029)		18.1 (4.9)	.50 (.097)		.21 (.047)	−.15 (.21)	.803
M_{Pt}	.09 (.043)	−.19 (.041)		−.01 (.028)	−4.9 (3.6)		.22 (.18)		−.15 (.25)	.507

price change in choice beef during the third and fourth quarters and only 10 per cent of the change during the first and second quarters. One possible explanation of this difference lies in variations in the relative importance of choice beef as a proportion of total meat. Choice beef is of less relative importance during the third and fourth quarters. During the third quarter large quantities of grass-fed cattle, which grade below choice, are marketed, and pork supplies reach their seasonal peak during the fourth quarter. During these periods there is less pressure on retail prices to follow wholesale prices, and changes in retail prices of choice beef will be influenced more by changes in prices of competing meats than by changes in the wholesale price of choice beef.

The results of the estimation for beef suggest that margins are positively associated with the wholesale price level and with wage rates. Further, the sizable coefficient for the lagged margin (0.50) suggests that there is a lag in beef margin adjustment as well as in the retail price adjustment.

Only the coefficients for the wholesale price changes exceed twice their standard errors in the pork equation. In neither equation does the estimated autocorrelation coefficient exceed twice its standard error. In

regressions fitted under the assumption that $\beta = 0$ the d statistic accepted at the 5 per cent level the null hypothesis of no positive autocorrelation in the residuals.

Packer-Wholesaler Behavior

Rather than attempt to describe behavior of this part of the marketing sector with supply and demand equations, two equations which can be derived from the supply and demand equations will be used: a storage equation and a margin equation. While the margin represents the difference between the demand price and the supply price, the change in stocks represents the difference between the quantity supplied and the quantity demanded.

Meat stocks

Meat inventories are desired for two purposes: to meet the day-to-day operational requirements and in anticipation of a price rise. Due to the large seasonal variation in production, large quantities of meat are stored for the seasonal price rise. It is possible to demonstrate that anticipated profit will be maximized when the marginal cost of storage is equated with the expected price rise.

Thus the optimum or desired level of pork stocks can be expressed as a function of the expected price rise as

$$(13) \qquad {}_{E}S_{Pt} = a\triangle p^{*}{}_{Pt+1} = a(p^{*}{}_{Pt+1} - p_{Pt})$$

where

$p^{*}{}_{t+1}$ = expectation held during period t for the value of p_{t+1},
${}_{E}S_{t}$ = equilibrium (i.e., desired) level of end of period stocks,
S_{t} = end of period stocks.

Since the expected price change is not an observable variable it is necessary to formulate a model for price expectations which permits the expression of stock behavior in terms of observable variables.

Nerlove has suggested the following model for generating price expectations:[14]

$$p^{*}{}_{t} - p^{*}{}_{t-1} = \alpha(p_{t-1} - p^{*}{}_{t-1})$$

which is equivalent to

$$p^{*}{}_{t} = \alpha \sum_{i=1}^{\infty} (1 - \alpha)^{i} p_{t-i}.$$

It is probable that this model is more applicable to a situation where action is fixed for a discrete time period once a decision has been made

[14] Marc Nerlove, *The Dynamics of Supply: Estimation of Farmers' Response to Price*, Baltimore: The Johns Hopkins Press, 1958, pp. 46-59.

than to the more flexible and dynamic inventory case, which is characterized by a considerable period of accumulation as well as depletion. In the latter case, expectations may be formulated for several future periods and these expectations reviewed, if not continuously, at least periodically.

In their study of meat inventories, Tolley and Harrell concluded that packers were fairly successful in predicting changes in supply but unsuccessful in forecasting shifts in demand.[15] Packers indicated that they used the Department of Agriculture "Pig Crop Report" when making their decisions concerning the accumulation of storage stocks. This suggests that price expectations are formed on the basis of supply expectations,

$$\triangle p^*_{Pt+1} = d_0 \triangle Q^*_{Bt+1} + d_1 \triangle Q^*_{Pt+1} \tag{14}$$

where

Q_t = volume of farm production during period t in millions of pounds,
Q^*_t = expectations held during $t-1$ concerning value of Q_t.

This formulation explicitly allows consideration of the substitute meat.

Applying to beef quantity the kind of expectation generating mechanism suggested by Nerlove, we obtain

$$\triangle Q^*_{Bt+1} = Q^*_{Bt+1} - Q_{Bt} = (1 - \alpha_0)(\triangle Q^*_{Bt} - \triangle Q_{Bt}) \tag{15}$$

For pork the model is modified by the addition of a variable to reflect changes in farrowings:

$$\triangle Q^*_{Pt+1} = Q^*_{Pt+1} - Q_{Pt} = (1 - \alpha_0)(\triangle Q^*_{Pt} - \triangle Q_{Pt}) + \alpha_1 \triangle F_t \tag{16}$$

where

$\triangle F_t$ = spring farrowings minus fall farrowings (in millions of pigs) measured from its mean value for the period studied.

(This variable enters the model only during the first and fourth quarters, when pork inventories ordinarily increase.)

Equation (15) relates expected change in beef production to a weighted average of current and past changes in production; (16) relates expected changes in pork production to a weighted average of current and past changes in pork production and a weighted average of changes in farrowings.

Our estimation procedure is equivalent to including trend and seasonal variables in the estimation equation. That is, such a procedure permits expected supplies as given by (15) and (16) to vary seasonally and to contain a trend component.

[15] George S. Tolley and Cleon Harrell, *Inventories in the Meat-Packing Industry*, Agr. Ec. Info. Ser. 58, N. C. State Coll., Dec. 1957, p. 45.

Equation (13) specifies the equilibrium level of end of period stocks. Businessmen are apt to have greater confidence in their prediction of direction of movement than in their prediction of magnitude of movement. This may cause them to adjust actual stocks by only a fraction of the predicted change indicated by (13).

If this fraction is a constant over time, the relation between actual and desired stocks becomes

$$S_{Pt} - S_{Pt-1} = \beta_0({}_E S_{Pt} - S_{Pt-1}) \tag{17}$$

The five equations (13) to (17) can be reduced to the equation to be estimated[16]

$$\begin{aligned} S_{Pt} = {} & (2 - \alpha_0 - \beta_0)S_{Pt-1} - (1 - \alpha_0)(1 - \beta_0)S_{Pt-2} \\ & - \beta_0(1 - \alpha_0)b_0\triangle Q_{Bt} - \beta_0(1 - \alpha_0)b_1\triangle Q_{Pt} + \alpha_1\beta_0 b_1\triangle F_t \end{aligned} \tag{18}$$

where $b_0 = d_0/a$ and $b_1 = d_1/a$.

Economists frequently invoke the acceleration principle to relate inventories to past sales. Because of Tolley and Harrell's finding that packers are more successful in predicting farm supply than in predicting demand, (13) might contain expected supply (instead of expected sales) in addition to expected price change. Making this addition would not change the variables in (18) but would change the coefficients of $\triangle Q_{Bt}$ and $\triangle Q_{Pt}$.

In the beef inventory equation, investigation of scatter diagrams led to the inclusion of

$$\begin{aligned} \triangle Q'_{Bt} &= \triangle Q_{Bt} \text{ during the first, second and third quarters,} \\ &= -3\triangle Q_{Bt} \text{ during the fourth quarter.} \end{aligned}$$

In the pork stocks equation, investigation of scatter diagrams led to the inclusion of

$$\begin{aligned} \triangle Q'_{Pt} &= -2\triangle Q_{Pt} \text{ during the second quarter} \\ &= \triangle Q_{Pt} \text{ during the first, third and fourth quarters.} \end{aligned}$$

Estimation of the storage equations yielded the results presented in Table 3. Apparently the change in production of beef exerts a greater influence on beef stocks during the quarter of accumulation than during periods of depletion, stocks absorbing about 10 per cent of the production change during the first, second and third quarters and about 26 per cent during the fourth quarter.

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[16] To derive equation (18) substitute (14) into (13), then substitute the expression for $\triangle Q^*_{t+1}$ from (15) and (16). This gives

$${}_E S_{Pt} = (1 - \alpha_0){}_E S_{Pt-1} - b_0(1 - \alpha_0)\triangle Q_{Bt} - b_1(1 - \alpha_0)\triangle Q_{Pt} + b_1\alpha_1\triangle F_t$$

Then substitute for ${}_E S_{Pt}$ and ${}_E S_{Pt-1}$ from (17) and (17) lagged one period.

TABLE 3. STATISTICS FROM ESTIMATION OF STOCK EQUATIONS

Dependent variable	$\triangle Q_{Bt}$	$\triangle Q_{Pt}$	S_{Bt-1}	S_{Pt-1}	S_{Bt-2}	S_{Pt-2}	$\triangle F_t$	$\triangle Q'_{Bt}$	$\triangle Q'_{Pt}$	β	R^2
S_{Bt}	.14 (.024)	.05 (.018)	.93 (.14)		−.24 (.12)			−.04 (.014)		.05 (.25)	.882
S_{Pt}	.02 (.056)	.30 (.041)		1.15 (.10)		−.38 (.09)	7.20 (3.10)		.05 (.024)	−.07 (.19)	.885

A greater decrease in pork production was required to elicit a given change in pork stocks during the second quarter—which is generally followed by increasing prices—than during the other quarters. About 35 per cent of the quarterly change in farm production is absorbed by changes in stocks during the first, third, and fourth quarters, and about 20 per cent during the second quarter.

The production change in pork had a significant positive effect upon beef stocks, but the production change in beef had little apparent effect upon pork stocks.

In the pork equation, the coefficient for $\triangle F_t$ exceeds twice its standard error and indicates that packers are more willing to store pork when the fall pig crop is small relative to the spring pig crop. The inclusion of $\triangle F_t$ in the beef equation yielded a nonsignificant coefficient of less than .05.

Equation (13) defines the functional relationship between the parameters α_0 and β_0 of the model and the coefficients of S_{Pt-1} and S_{Pt-2}. An analogous equation specifies a similar relationship between α_0 and β_1 (the coefficient of adjustment for beef stocks) and the coefficients of S_{Bt-1} and S_{Bt-2}.

Let c_{P1} and c_{P2} represent the coefficients of S_{Pt-1} and S_{Pt-2} in (13). Let c_{B1} and c_{B2} represent the coefficients of S_{Bt-1} and S_{Bt-2} in the equation (similar to 13) for beef stocks. The model specifies that $c_{P2} - c_{B2} = (1 - \alpha_0)(c_{P1} - c_{B1})$. The coefficients in Table 3 were obtained ignoring this restriction. Use of these coefficients to estimate α_0, β_0 and β_1 leads to complex numbers. Imposing the restriction and applying an approximate maximum likelihood estimation procedure, the following estimates and approximate standard errors are obtained:

α_0, the common coefficient of expectation: 0.45 (0.37)
β_1, the coefficient of adjustment for beef stocks: 0.64 (0.41)
β_0, the coefficient of adjustment for pork stocks: 0.42 (0.37)

Note that the above estimates yield coefficients for S_{t-1} and S_{t-2} very little different from those of the table (and the sum of these coefficients differs even less from the sum of those given in the table) and hence the imposition of the model restrictions on the coefficients increases the residual mean square very slightly. This phenomenon also explains the large standard errors for α_0, β_1, and β_0, i.e., these estimates have large

negative covariances and, hence, the sum and product can be estimated with variances much smaller than the variances of the individual estimates.

Farm-to-wholesale margin

Included in the farm-to-wholesale margin are both the increase in value due to processing and the charge for the wholesaling service. Of the cost elements associated with this margin, labor is the most important, representing approximately 50 per cent of the difference between the cost of livestock and the receipts from sales at wholesale.[17] It appears that the cost of changing the level of operation is an important consideration in meat packing. Breimeyer notes that margins fluctuate more than the costs associated with changes in production due to "the desire of the entire meat trade for stability in both prices and volume of business."[18]

One might expect the wholesale margin for beef to be related to that for pork or to be related to the production of pork, since beef and pork are often processed in the same plants or by the same firms in different plants.

It is possible that meat packers, as wholesalers, practice some type of average cost pricing. Also margins may be influenced by shifts in demand as these shifts are reflected in changes in wholesale prices.

The following model, therefore, was formulated:

$$(19) \qquad {}_E m_{Pt} = a_0 p_{Pt} + a_1 w_t$$

$$(20) \qquad m_{Pt} - m_{Pt-1} = b_0({}_E m_{Pt} - m_{Pt-1}) + b_1 \triangle Q_{Pt} + b_2 \triangle Q_{Bt} + b_3 \triangle p_{Pt}$$

where:

m_t = deflated farm-to-wholesale marketing margin during period t in dollars per 100 pounds live weight,

${}_E m_t$ = equilibrium value of m_t,

w_t = current wage rate of employees in meat processing establishments.

The wholesale price used in this analysis is on a live weight basis and includes the value of by-products and minor cuts.

The following reduced equation results:

$$(21) \qquad m_{Pt} = a_0 b_0 p_{Pt} + a_1 b_0 w_t + b_1 \triangle Q_{Pt} + b_2 \triangle Q_{Bt} + b_3 \triangle p_{Pt} + (1 - b_0) m_{Pt-1}$$

A slightly modified model was formulated for beef margins. Since the beef margin data pertain to choice grade beef, a variable denoted as Ch_t

[17] U.S. Dept. Agr., *Beef Marketing Margins and Costs*, Misc. Publ. 710, Feb. 1956, p. 13.

[18] Harold F. Breimeyer, "On Price Determination and Aggregate Price Theory," *J. Farm Econ.*, 34:676-94, 1957.

was included to represent the portion of farm marketings which grade choice. This variable is defined as the per cent of all slaughter steers at Chicago, Omaha and Sioux City grading prime or choice. For beef, then, equilibrium margin was specified as

$$(22) \qquad {}_E m_{Bt} = \alpha_0 p_{Bt} + \alpha_1 w_t + \alpha_2 Ch_t$$

The margin adjustment equation for beef is analogous to that for pork. First fittings of these models yielded very low coefficients (relative to their standard errors) for wages, for the change in quantity of the competing meat and for $\triangle p_{Pt}$. Consequently these variables are not included in the equations presented here. The following variable was included in the pork equation upon examination of the scatter diagrams:

$$\begin{aligned} \triangle Q'_{Pt} &= -\triangle Q_{Pt} \text{ third quarter} \\ &= \triangle Q_{Pt} \text{ first quarter} \\ &= 0 \text{ otherwise} \end{aligned}$$

The results (Table 4) indicate that the change in pork production has little effect upon first quarter pork margins, but is a very important determinant of third quarter margins. For the third quarter the pork margins increased about 18 cents for each 100 million pounds increase in production. Margins increased about 8 cents for the same increase in production during the second and fourth quarters.

The coefficient for the change in production of beef in the beef margin equation indicates that the beef margin increases 11 cents for each 100 million pounds that production increases. Note, however, that the coefficient for the change in the wholesale price is positive, indicating a decrease in the margin as the wholesale price decreases.

For beef, the coefficient for the lagged margin exceeds twice its standard error, suggesting that there is a lag in margin adjustment.

The coefficient for lagged pork margin is sizable, but exceeds only moderately its standard error and the value of β is less than its standard error. The sum of the two coefficients is 0.58; its standard error is 0.13. There is some type of lag present in the system, but the data fail to differentiate between a lag arising from autocorrelated errors and a lag arising from the adjustment process.

TABLE 4. STATISTICS FROM ESTIMATION OF FARM-TO-WHOLESALE MARGIN EQUATIONS

Dependent Variable	$\triangle Q_{Bt}$	$\triangle Q_{Pt}$	p_{Bt}	p_{Pt}	Ch_t	$\triangle p_{Bt}$	$\triangle Q'_{Pt}$	m_{Bt-1}	m_{Pt-1}	β	R^2
m_{Bt}	.00112 (.00052)		−.02 (.014)		.030 (.0066)	.063 (.036)		.36 (.16)		−.25 (.23)	.560
m_{Pt}		.00077 (.00022)		−.02 (.018)			−.00102 (.00034)		.40 (.22)	.18 (.26)	.650

In neither equation did the coefficient for wholesale price exceed twice its standard error. Thus, the data would fail to refute the hypothesis that the level of price (in constant dollars) has no effect upon the margin.

Summary and Conclusions

Estimation of consumer demand equations containing lagged quantity suggested that price flexibility was greater (in absolute value) in the long run. However, only in the case of beef was the difference between the short run and long run flexibility sizable relative to the standard error.

Lags in the marketing channel seemed to be more pronounced in the case of beef than in the case of pork. Although the margins of both were affected by changes in prices and/or quantities, only in the beef equations were lagged margins important explanatory variables.

Estimation of the stock equations suggests that models should consider both expectations and lags in adjusting to these expectations. The estimation also points up the difficulty in estimating separately the parameters associated with these two types of adjustment.

(See next page for Appendix)

Appendix

REGRESSION EQUATIONS DEFINING VARIABLES USED IN ANALYSIS

Variable	Constant	Time	D_1	D_2	D_3
Y_t	12.93	0.063 (0.004)	−0.016 (0.043)	0.001 (0.061)	0.025 (0.062)
C_{Bt}	14.84	0.170 (0.019)	0.26 (0.24)	−0.41 (0.33)	−0.05 (0.34)
C_{Pt}	17.44	−0.038 (0.014)	0.23 (0.17)	1.85 (0.24)	0.95 (0.24)
P_{Bt}	58.74	−0.27 (0.07)	0.33 (0.84)	0.02 (1.17)	−0.01 (1.20)
P_{Pt}	55.13	−0.19 (0.05)	0.60 (0.57)	−2.07 (0.80)	−1.14 (0.82)
${}_1C_{Pt}{}^2$	4.81	−0.06 (0.04)	1.07 (0.52)	1.60 (0.72)	0.01 (0.74)
M_{Bt}	11.20	0.084 (0.014)	−0.05 (0.17)	0.19 (0.24)	−0.05 (0.25)
M_{Pt}	10.37	0.058 (0.010)	0.53 (0.13)	0.58 (0.18)	0.21 (0.18)
$\triangle p_{Bt}$	−0.09	−0.001 (0.030)	0.32 (0.37)	−0.90 (0.52)	−0.48 (0.53)
$\triangle p_{Pt}$	−0.05	−0.010 (0.033)	−1.86 (0.41)	−3.40 (0.58)	−0.64 (0.59)
p_{Bt}	47.54	−0.35 (0.06)	0.38 (0.74)	−0.7 (1.04)	0.04 (1.07)
p_{Pt}	44.58	−0.24 (0.05)	0.02 (0.61)	−2.74 (0.85)	−1.35 (0.87)
W_t	1.17	0.0091 (0.0003)	−0.0015 (0.0039)	0.0015 (0.0055)	0.0021 (0.0056)
Ch_t	69.28	−0.12 (0.08)	6.15 (0.99)	−1.24 (1.39)	−3.72 (1.42)
m_{Bt}	2.29	−0.002 (0.005)	0.22 (0.06)	−0.16 (0.08)	−0.03 (0.08)
m_{Pt}	4.23	0.010 (0.004)	0.23 (0.05)	0.04 (0.07)	0.15 (0.07)
S_{Bt}	136.01	0.67 (0.54)	4 (7)	37 (9)	17 (9)
S_{Pt}	539.02	−0.75 (1.08)	−82 (13)	89 (19)	38 (19)
$\triangle Q_{Bt}$	37.26	−0.31 (1.43)	63 (18)	−88 (25)	−57 (25)
$\triangle Q_{Pt}$	1.62	0.48 (2.03)	324 (25)	441 (35)	89 (35)

ADVERTISING WITHOUT SUPPLY CONTROL: SOME IMPLICATIONS OF A STUDY OF THE ADVERTISING OF ORANGES

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> In this world . . . every plain and simple doctrine as to relations between cost of production, demand and value is necessarily false.—A. MARSHALL

MANY economists tend to think of advertising and promotion as phenomena encountered primarily under imperfectly competitive conditions: conditions under which those decision makers controlling expenditures on advertising also possess a considerable degree of control over output or price, or under which advertising is used primarily to achieve such control.[1] Actually, large promotional expenditures are made by groups of producers, processors, and distributors of agricultural products, by voluntary trade associations, and by State Commissions, none of which exercise significant control over the aggregate volume of marketings or over prices. Consequently, we believe that there is a need for a more realistic theory of advertising without supply control and for statistical measurement of the effects of advertising upon the total and net returns of producers.

In order to simplify our terminology, we shall use the term "cooperative advertising" to include all promotional expenditures by any group which exercises little or no control over supplies. "Advertising," in this sense,

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The conclusions of this paper are entirely our own. They do not in any way implicate any of the above gentlemen, nor do they represent the official views of the Economic Research Service.

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Bracketed numbers refer to the list of references at the end of the paper.

[1] See for example: Buchanan [4], Chamberlin [5], Dorfman and Steiner [6], Hahn [7], Kaldor [10], Samuelson [13, pp. 41-42], Wellman [17], and Yntema [20].

covers public relations, demonstrations, store displays, and the like, as well as those items more usually identified with our term. "Cooperative" includes any organized professional or trade group or governmental agency which helps to promote goods or services.[2] There are many such groups or agencies, both within and without the agricultural sector.

The present paper is intended to supplement existing theoretical and statistical knowledge of advertising. In particular, we are concerned with (1) the theory of cooperative advertising, and (2) the quantitative effect of such advertising on demand.[3] Following the theoretical analysis, we present a statistical analysis of the effects of advertising on the demand for oranges and illustrate the potential uses of the theory. Our theoretical analysis is static in nature and concerned with the economically optimal expenditure on advertising in the long run. When supplies are uncontrolled, the latter is found to depend on several factors: (1) the price elasticity of demand, (2) the long-run effects of advertising expenditures on demand, (3) the price elasticity of industry supply, (4) the nature and extent of external economies or diseconomies of scale to the industry, and (5) the rate of return on alternative forms of investment. Only the first two of these have been quantitatively investigated in the present paper, but plausible assumptions concerning the magnitudes of the three last mentioned lead to results comparable to actual expenditures in recent years.

I. A Static Theory of Cooperative Advertising

In our model, what we have called a cooperative has no *direct* control over output or price. But its advertising expenditures may affect both output and price *indirectly*. The reason is that advertising expenditures shift the demand curve for the product by attracting new consumers and altering the tastes and preferences of former buyers. Of course, this shift is not accomplished instantaneously nor do the effects of a dollar spent on advertising disappear at once.[4] However, for our purposes we con-

[2] In the case of oranges, for example, Sunkist Growers (California) are a cooperative, whose primary function is to market the crops of its members, whereas the Florida Citrus Commission is an agency of the state government that carries out certain regulatory and promotional programs.

[3] Some of the problems involved in the measurement of returns from the promotion of farm products are discussed by Hoos [8], but he does not distinguish between the problems faced by a monopolist, who can control output, and a group of producers who cannot. Previous attempts to measure the effects of advertising on demand include: Apodaca [2], Wolf [18], Borden [3], and Vidale and Wolfe [15].

[4] An earlier paper by Waugh [16] stressed the dynamic nature of the relation of advertising expenditures to demand and suggested the use of distributed lags in this connection. Perhaps the first indication of the utility of the distributed lag concept in the study of the effects of advertising on demand is given in Sasuly [14]. Sasuly's idea is further developed in Jastram [9]. We have made some use of this concept in developing a statistical model for orange demand, but have not incorporated the dynamic aspects thus introduced into the present discussion of optimal cooperative advertising policy.

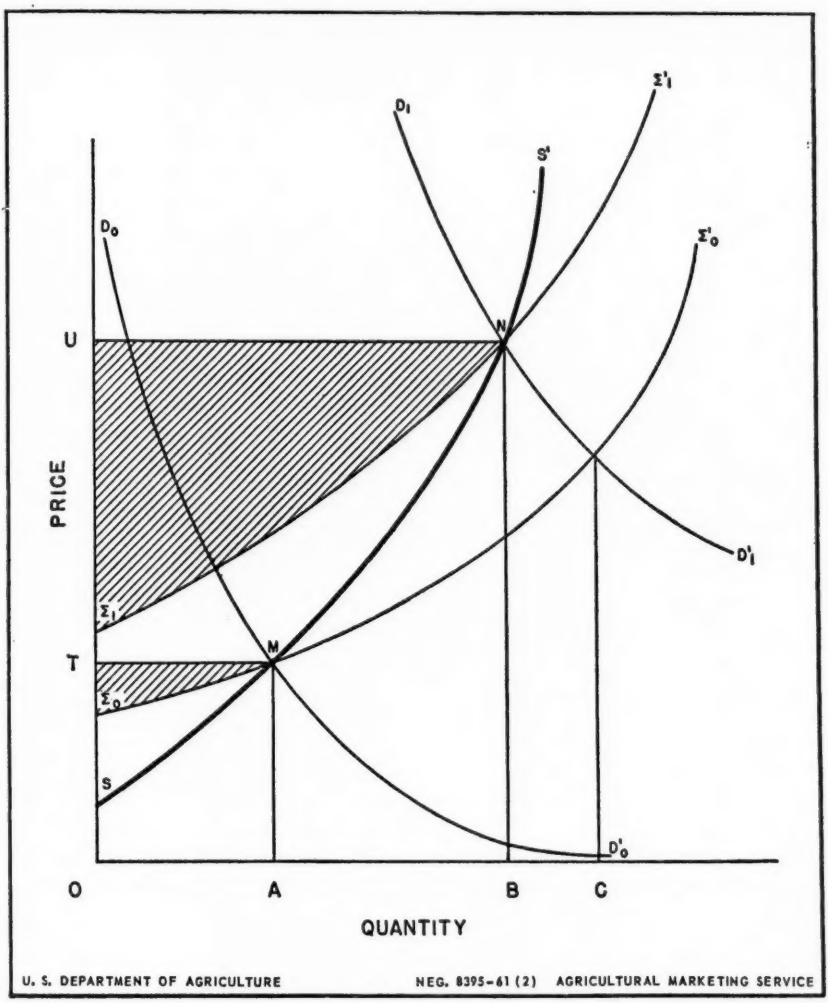

FIGURE 1. EFFECT OF INCREASED ADVERTISING UPON PRICE AND QUANTITY: EXTERNAL DISECONOMIES.

sider only the long-run, ultimate effects of advertising on demand and supply.

In contrast to the theory of advertising under conditions of imperfect competition, a theory of advertising without supply control need not consider the effects of advertising on the price elasticity of demand and the cross-elasticities of demand with respect to the prices of competing commodities. This is an important difference between existing theories of advertising and the theory we develop below.

Because advertising expenditures shift the demand curve for a product, they also affect both the price and quantity. This is illustrated in Figure

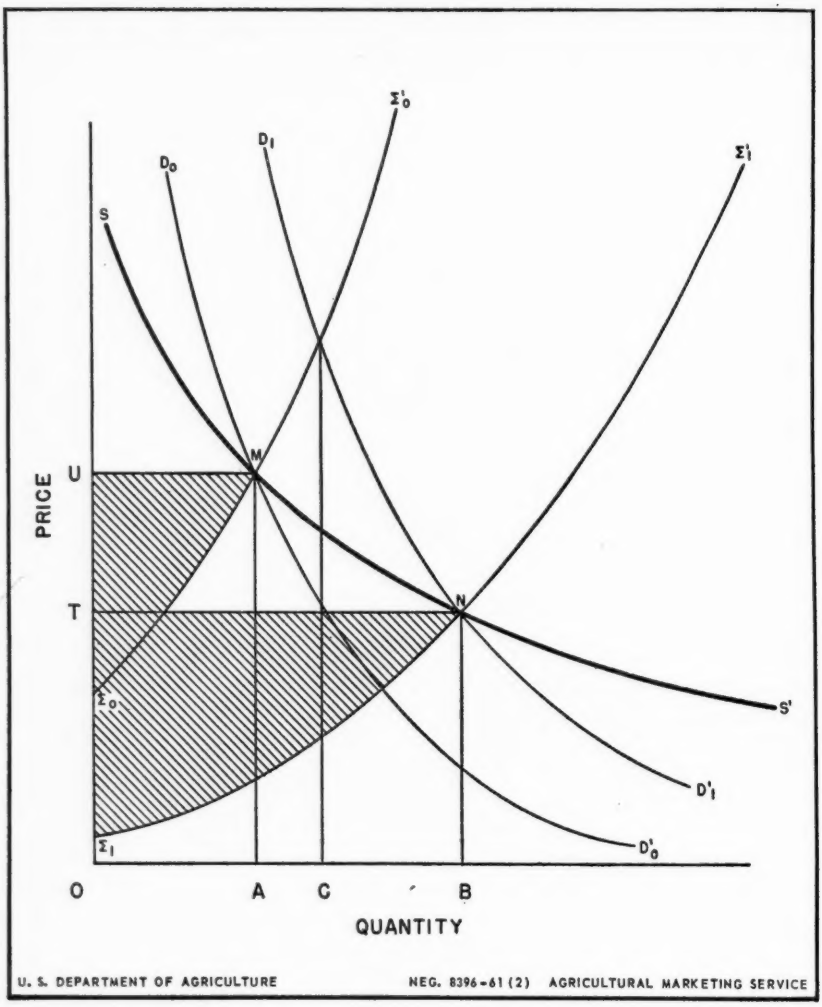

FIGURE 2. EFFECT OF INCREASED ADVERTISING UPON PRICE AND QUANTITY: EXTERNAL ECONOMIES.

1: Increased advertising expenditures shift the demand curve from $D_0D'_0$ to $D_1D'_1$; but because, by assumption, producers as a group do not directly control supply, the long-run effect of the shift in the demand curve is a movement along the industry supply curve SS', so that quantity increases from A to B and price from T to U. If the industry supply schedule were downward sloping or if improvements in technology occurred during the interval so that the supply schedule shifted to the right, we might actually observe both an increased quantity and a lower price. (See Figure 2.) In general, however, it should be true that advertising expenditures will raise the total value of the crop.

It is useful at this point to distinguish between the sum of the individual supply curves of current and potential producers of the commodity in question and the industry supply curve. The former is the sum of the individual marginal cost curves where such lie above average costs; factor prices are held constant although the quality of factors, e.g., land, may differ from firm to firm. If there are neither external economies nor diseconomies of scale to the industry, the industry supply function is identical to the sum of the individual firm supply curves. When there are external diseconomies of scale, however, the industry supply curve, SS', rises more sharply than the sums of the firm supply curves. The latter are shown as $\Sigma_0\Sigma_0'$ and $\Sigma_1\Sigma_1'$, in Figure 1. When demand is shifted b yadvertising from $D_0D'_0$ to $D_1D'_1$, we would expect total output to increase from A to C if we did not take account of external diseconomies; but when industry output increases, prices of some of the factors of production may increase (pecuniary diseconomies) and other problems such as increased susceptibility to disease (non-pecuniary diseconomies) may arise; hence, the Σ-curve shifts and industry output increases only to B.[5]

The situation in which external economies of scale predominate is analogous. In this case the industry supply curve (S-curve) rises less sharply than the Σ-curves. This is illustrated in Figure 2 for a case in which economies of scale so outweigh diseconomies that the S-curve is forward-falling. Thus, when demand shifts from $D_0D'_0$ to $D_1D'_1$, industry output increases not from A to C but from A to B, since in consequence of the industry expansion the Σ-curve shifts from $\Sigma_0\Sigma'_0$ to $\Sigma_1\Sigma'_1$. The reason for such a shift may be economies of either a pecuniary or a non-pecuniary kind; for example, an increase in the output of the orange industry may have enabled growers to use more machinery and mass-production methods on the farm, in transportation, and in processing.

Let

p = the price of the commodity
q = the quantity of the commodity
a = advertising expenditures
v = the total dollar value of the quantity marketed = pq.

[5] Note that the distinction between the Σ-curves and the industry supply curve is *not* related to the distinction between long-run and short-run adjustments. Although it is tempting to draw a parallel, the reader should continually bear in mind that our entire analysis is of a long-run character. The important distinction to be made here is that between effects *external* to the firms in, or potentially in, the industry, and effects *internal* to them. Thus the Σ-curves rise both because of *internal* diseconomies of scale (rising marginal costs) and because the new firms drawn into the industry may be possessed of inferior resources. The fact that the industry supply curve does not necessarily correspond to a unique Σ-curve is the result solely of effects *external* to the firms in, or potentially in, the industry which shift the marginal cost curves of these firms. Note too that what external factors affect supply or cost conditions, and what affect demand conditions depend in part on the level of the analysis. Thus changes in marketing practices affect *demand* if the analysis pertains to oranges at the farm level, whereas they affect *supply* if the analysis pertains to the retail level.

For the moment we assume all other variables affecting demand or supply to be held constant and do not specify at what market level price is measured. Then we may write the demand function as

$$q = D(p, a) \tag{1}$$

and the industry supply function as

$$q = S(p). \tag{2}$$

Market equilibrium requires that the quantities demanded and supplied be equal. The effect of a change in advertising expenditures on price and quantity is found by differentiating (1) and (2) with respect to a and solving the resulting equations for

$$\frac{\partial p}{\partial a} \quad \text{and} \quad \frac{\partial q}{\partial a}.$$ [6]

Differentiating (1) and (2) with respect to a yields

$$\begin{cases} \dfrac{\partial q}{\partial a} - \dfrac{\partial D}{\partial p}\dfrac{\partial p}{\partial a} = \dfrac{\partial D}{\partial a} \\ \dfrac{\partial q}{\partial a} - \dfrac{\partial S}{\partial p}\dfrac{\partial p}{\partial a} = 0, \end{cases} \tag{3}$$

so that

$$\frac{\partial q}{\partial a} = \frac{\dfrac{\partial D}{\partial a}\dfrac{\partial S}{\partial p}}{\dfrac{\partial S}{\partial p} - \dfrac{\partial D}{\partial p}} \tag{4}$$

and

$$\frac{\partial p}{\partial a} = \frac{\dfrac{\partial D}{\partial a}}{\dfrac{\partial S}{\partial p} - \dfrac{\partial D}{\partial p}}. \tag{5}$$

As usual in comparative static analyses, the signs of these derivatives may be related to the question of whether the equilibrium of demand and supply is stable or not. But the concept of stability which is useful here is the *Marshallian* one. If the industry supply curve is upward sloping and the demand downward, an upward shift in the demand curve resulting from increased advertising expenditures will result in both an increased price and an increase in marketings. On the other hand, if the industry supply curve is forward falling in the Marshallian sense, we

[6] See Samuelson [13, pp. 7-29 and 258-60]. The results given in the text are a well-known application of the principles of comparative statics to the problem of the incidence of a shift in the demand schedule.

must have a supply curve which cuts the demand curve from below in order to have stability; i.e.,

$$\frac{\partial S}{\partial p} < \frac{\partial D}{\partial p}.$$ [7]

Consequently, industry output must always increase as the result of an increase in advertising expenditures if we assume stability. But in this case the price is reduced.

Using the results of (3) and (4) we can find the effect of an increase in advertising expenditures on the dollar value of marketings; it is simply

$$\frac{\partial v}{\partial a} = p\frac{\partial q}{\partial a} + q\frac{\partial p}{\partial a} = \frac{p\dfrac{\partial S}{\partial p} + q}{\dfrac{\partial S}{\partial p} - \dfrac{\partial D}{\partial p}}\,\frac{\partial D}{\partial a}. \tag{6}$$

For a rising industry supply curve

$$\frac{\partial v}{\partial a}$$

will always be positive; it may be negative if the industry schedule is forward falling and has an elasticity between zero and -1.

Dividing both numerator and denominator of the right-hand side of (6) by q and multiplying both by p we have

$$\frac{\partial v}{\partial a} = \frac{1 + \dfrac{p}{q}\dfrac{\partial S}{\partial p}}{\dfrac{p}{q}\dfrac{\partial S}{\partial p} - \dfrac{p}{q}\dfrac{\partial D}{\partial p}}\left(p\frac{\partial D}{\partial a}\right) = \frac{1+\epsilon}{\epsilon - \eta}\alpha \tag{7}$$

where ϵ = the elasticity of industry supply, η = the elasticity of demand with respect to price, and α may be interpreted as the marginal gross revenue from increased advertising expenditures, *holding prices constant.* In other words, α represents the increase in the dollar value of marketings which would occur if industry supply were perfectly elastic at a price p.

In the case of oranges during the past fifty years, there has in fact been a fall in the real price but an increase in quantity and in the real total value of the crop. This could be a result of a forward falling supply schedule, as indicated; but the same observations could also have resulted from autonomous shifts in the industry supply curve over which the cooperatives had no control, either direct or indirect. A theory of cooperative

[7] Samuelson [13, p. 264]. See also Adams and Wheeler [1].

advertising can be developed which applies either to the situation in which there are no external economies or diseconomies but in which there are autonomous shifts, or to the situation in which there are recognized external economies or diseconomies. The important distinction is not what is true in reality but what the cooperative believes to be true. Thus, from the standpoint of our theory it makes no difference whether in fact the industry supply curve is the Σ-curve but autonomous forces shift it, or whether in fact the industry supply curve is different from the Σ-curves but the cooperative takes no account of the effects of its actions in creating external economies or diseconomies. On the other hand, if the industry supply is different from the Σ-curves, and producers are aware of this difference, it will affect our results.

In what follows, we attempt to discover the most profitable amount for a group to spend on cooperative advertising, i.e., to develop a *normative* theory of cooperative advertising; and further to inquire whether such a theory has predictive value in the sense that it can explain advertising behavior when supplies are uncontrolled.

Presumably a cooperative, or any organized group of producers, tries to further the best interests of its members. If advertising programs are financed by either voluntary or compulsory payments by producers, it is difficult to define unambiguously a rate of payments which would most benefit the group as a whole. Since payments must generally be approved by a majority of producers, rates must be kept low enough to continue to attract majority support. Any purely economic theory of cooperative advertising can thus only set an upper bound to optimal expenditures.

Rather than search for an absolute answer to the question of what expenditures would be optimal in given circumstances, we shall consider a level to be optimal if it maximizes some aggregate of the profits of individual producers, net of both individual production costs and collective advertising expenditures.

Marshall [11, pp. 367-80 and 810-11] calls the sum of individual producers' marginal cost curves (our Σ-curve) the "particular expenses curve," and it is in terms of the particular expenses curve that he defines the concept of producers' surplus: It is the difference between aggregate variable costs of production and aggregate revenue. Since our Σ-curves are sums of individual marginal costs curves, the area under a Σ-curve to a given industry output represents the total variable cost of that output; deducting this amount from revenues yields producers' surplus, which is an aggregate of producers' profits and quasi-rents to fixed or especially adapted factors of production.[8] The areas representing producers' surplus for various levels of demand are shaded in Figures 1 and 2.

[8] Some land is just better for growing oranges than other land. If ownership of the land and production are separated, quasi-rents accruing to the better land may be re-

Let π = producers' surplus. π is a function of industry output, of cooperative advertising expenditures, and of other variables over which producers as a group exercise neither direct nor indirect control. It should be noted that industry output depends indirectly on the level of cooperative advertising expenditures. Returns from advertising, R, may be defined as the differences between producers' surplus and advertising expenditure

$$R = \pi - a. \tag{8}$$

Provided producers have no alternative productive uses for the funds spent on advertising, our theory suggests a level of advertising expenditure which equates marginal returns to advertising, $\partial R/\partial a$, to zero. But this is optimal only if the money devoted to advertising could not profitably be devoted to some other alternative. For example, each producer could devote the funds which might otherwise be collected from him to the purchase of government bonds, thus realizing for each dollar so utilized the original dollar plus interest. In this case, marginal returns should be equated not to zero but to the rate of return on alternative forms of investment ρ. In mathematical form our theory of cooperative advertising is then that a is determined by the condition

$$\frac{\partial R}{\partial a} = \rho. \tag{9}$$

If $\partial R/\partial a$ exceeds ρ, the cooperative should increase advertising expenditures; and, conversely, if $\partial R/\partial a$ is less than ρ, it should reduce expenditures.

A more explicit formulation is not possible unless we specify more completely the relation between the industry supply curves and the Σ-curves. In the next two sections more explicit formulations are given.

II. Optimal Cooperative Advertising Policy in the Absence of External Economies or Diseconomies

When there are no external economies or diseconomies to the industry, the industry supply curve corresponds to the Σ-curve, which is unique. In this case producers' surplus is

$$\pi = v - \int_0^q S^{-1}(t)dt,^{9} \tag{10}$$

so that

$$\frac{\partial R}{\partial a} = \frac{\partial v}{\partial a} - S^{-1}(q)\frac{\partial q}{\partial a} - 1 = p\frac{\partial q}{\partial a} + q\frac{\partial p}{\partial a} - p\frac{\partial q}{\partial a} - 1 \tag{11}$$

flected in actual rents. Such rents may nonetheless be included in producers' surplus. Some objection may be raised to our theory on this ground, although it is not implausible that the cooperative acts in the interest of landlords as well as producers. Alternatively, of course, one might simply treat land as a variable factor in the long run.

[9] $S^{-1}(q)$ is the industry supply curve written in inverse form; i.e., price as a func-

from (6). Transforming to elasticities in the manner used to derive (7), we find

$$\frac{\partial R}{\partial a} = \frac{\alpha}{\epsilon - \eta} - 1. \tag{12}$$

Thus, in the absence of external economies or diseconomies, optimal cooperative advertising policy is determined by the condition that

$$\frac{\alpha}{\epsilon - \eta} = 1 + \rho. \tag{13}$$

In a subsequent section we show how this expression may be used to derive a numerical value for optimal advertising expenditures.

III. Optimal Cooperative Advertising Expenditures in the Presence of External Economies or Diseconomies

When external economies or diseconomies are present, it is unfortunately no longer possible to derive so explicit a rule for the determination of optimal advertising expenditures without specifying the *forms* of the industry supply curve and the Σ-curves, and the relationship between the two. To facilitate the discussion, we assume that both Σ-curves and industry supply curve are of constant-elasticity form; this implies, as we show, a constant relationship between the two.

Let q^* = the sum of the outputs which would be produced by individual firms at a price p if external economies or diseconomies were those associated with industry output q; thus, a given Σ-curve determined by the particular industry output q may be written

$$q^* = \Sigma\,(p; q). \tag{14}$$

We assume that this is of constant-elasticity form:

$$q^* = k^* p^\sigma q^\omega \tag{15}$$

where σ is the price elasticity of the Σ-curve for *any* industry output; ω is a parameter reflecting external economies or diseconomies (if positive, economies, and if negative, diseconomies); and k^* is a constant. We also assume that the industry supply curve is of constant-elasticity form:

$$q = kp^\epsilon. \tag{16}$$

ϵ is the elasticity of industry supply, and k is a constant.

In equilibrium, $q = q^*$; i.e., the Σ-curve and the demand curve pass through the same point on the industry supply function. Hence, setting $q = q^*$ in (15) and solving for q,

$$q = k^{*1/(1-\omega)} p^{\sigma/(1-\omega)}.^{10} \tag{17}$$

tion of quantity. With external economies of scale marginal cost curves shift downward with an increase in industry output. Under competitive conditions, this means lower prices, but the lower prices do not *cause* the increase in output.

[10] Note that if $\omega = 1$, external economies exactly balance internal diseconomies so

Comparing (16) and (17), we deduce that

$$\omega = 1 - \frac{\sigma}{\epsilon}, \tag{18}$$

so that the Σ-curves may be rewritten without the explicit use of the scale parameter ω:

$$q^* = k^* p^\sigma q^{1-\sigma/\epsilon}. \tag{19}$$

Solving (19) for p, we obtain finally

$$p = k^{*\frac{-1}{\sigma}} q^{\frac{1}{\epsilon}-\frac{1}{\sigma}} q^{*\frac{1}{\sigma}}. \tag{20}$$

Aggregate variable costs of production, C, may be found by integrating (20) with respect to q^* to the industry output; i.e., as the area under the Σ-curve for a given industry output to that output:

$$\begin{aligned} C &= \int_0^q \Sigma^{-1}(t^*, q)\,dt^* \\ &= \int_0^q k^{*\frac{-1}{\sigma}} (q)^{\frac{1}{\epsilon}-\frac{1}{\sigma}} (t^*)^{\frac{1}{\sigma}}\,dt^* \\ &= k^{*\frac{-1}{\sigma}} (q)^{\frac{1}{\epsilon}-\frac{1}{\sigma}} \left[\frac{t^{*1+(1/\sigma)}}{1+\frac{1}{\sigma}}\right]_0^q \\ &= \left[\frac{k^{*-1/\sigma}}{1+\frac{1}{\sigma}}\right] q^{1+(1/\epsilon)}. \end{aligned} \tag{21}$$

Producers' surplus is the difference between gross revenues and variable costs

$$\pi = v - c.$$

Returns to advertising net of advertising expenditures are

$$R = \pi - a = v - c - a.$$

Marginal net returns to advertising may be found by differentiating R with respect to a and recalling that industry output and price are both functions of a indirectly:

$$\frac{\partial R}{\partial a} = \frac{\partial v}{\partial a} - \frac{\partial c}{\partial q}\frac{\partial q}{\partial a} - 1. \tag{22}$$

We may substitute for $\dfrac{\partial v}{\partial a}$ from (7). $\dfrac{\partial c}{\partial q}\dfrac{\partial q}{\partial a}$ may be evaluated from (21) as

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that the industry supply curve is perfectly elastic even though the Σ-curves are not. That the constant k^* does not really matter can be seen by choosing the quantity units so that $k^* = 1$.

follows:

$$\frac{\partial c}{\partial q}\frac{\partial q}{\partial a} = \left[\frac{k^{*-1/\sigma}}{1+1/\sigma}\right](1+1/\epsilon)q^{1/\epsilon}\frac{\partial q}{\partial a} \tag{23}$$
$$= [k^{*-1/\sigma}q^{1/\epsilon}]\left(\frac{1+1/\epsilon}{1+1/\sigma}\right)\frac{\partial q}{\partial a}.$$

From (17) we see that the expression in square brackets is actually the price of the product; hence, from (4)

$$\frac{\partial c}{\partial q}\frac{\partial q}{\partial a} = \left(\frac{1+1/\epsilon}{1+1/\sigma}\right)p\frac{\partial q}{\partial a}$$
$$= \left(\frac{1+1/\epsilon}{1+1/\sigma}\right)\left[\frac{p\dfrac{\partial D}{\partial a}\dfrac{\partial S}{\partial p}}{\dfrac{\partial S}{\partial p}-\dfrac{\partial D}{\partial p}}\right] \tag{24}$$
$$= \left(\frac{1+1/\epsilon}{1+1/\sigma}\right)\left(\frac{\epsilon\alpha}{\epsilon-\eta}\right).$$

It follows from (22) that

$$\frac{\partial R}{\partial a} = \left(\frac{1+\epsilon}{\epsilon-\eta}\right)\alpha - \left(\frac{\epsilon\alpha}{\epsilon-\eta}\right)\left(\frac{1+1/\epsilon}{1+1/\sigma}\right) - 1$$
$$= \frac{\alpha}{\epsilon-\eta}\left(\frac{1+\epsilon}{1+\sigma}\right) - 1.$$

Optimal cooperative advertising policy is determined by equating marginal net returns to advertising to the rate of return on alternative forms of investment:

$$\frac{\alpha}{\epsilon-\eta}\left(\frac{1+\epsilon}{1+\sigma}\right) = 1+\rho. \tag{25}$$

Note that (25) differs from our previous result (13) only by the inclusion of the term in parentheses. When $\varepsilon = \sigma$, this term is unity and (25) becomes (13). The condition $\varepsilon = \sigma$ is simply the condition that external economies or diseconomies are absent in the special case of constant-elasticity curves considered here.

IV. A Statistical Analysis of Advertising by Orange Growers

The theoretical formulation discussed in the preceding sections grew out of discussions of the implications of a statistical investigation of the effects of advertising expenditures on the demand for oranges. A theory was needed to explain the observed expenditures of orange growers on advertising, and to give some indication of possible short-term and long-

term effects to be expected if the advertising budget were increased or decreased.

The application of our theoretical formulation to these problems yields only an upper bound to optimal advertising expenditures. An additional difficulty arises from the fact that our analysis is wholely static in nature; i.e., we have described conditions under which a given flow of cooperative advertising expenditures will be economically optimal in the long run. No attempt has been made in the theoretical analysis to take account of the fact that the effects of advertising tend to persist for a time and then gradually die out, or of the fact that other forces are in operation shifting the demand and supply schedules. When a more general formulation is attempted, it turns out that optimal current advertising expenditures depend crucially on the expected rates of change of demand and supply shifters as well as on the persistence of advertising effects and the rate at which the future is discounted. This matter is discussed in another paper.[11]

Our choice of oranges and orange advertising was dictated primarily by the fact that we were able to get a complete history covering some fifty years of promotion.[12] Our statistical analysis covered only the *demand* for oranges, so that we obtained estimates of the price elasticity of demand, η, and the marginal gross returns from advertising, price constant, α, but not of the industry supply elasticity, ε, nor of the extent of external economies and diseconomies, nor of the rate of return on alternative forms of investment, ρ.[13]

While the results of our investigation appear to indicate that the advertising of oranges has affected demand substantially, they should not be construed as a case for the general advertising of farm products as a means for alleviating present difficulties. Such a view neglects both the rather special characteristics of oranges and the competition among different agricultural products for a share of the consumer budget.

In 1907-08, when orange growers started to advertise their product, the

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[11] The advertising problem under dynamic conditions has been discussed for a monopolist by Nerlove in an unpublished manuscript: "Optimal Advertising Policy Under Dynamic Conditions" (July 1959). It should be noted that advertising is formally identical to investment in a depreciating but non-salable fixed asset. Thus the problem of optimal advertising policy under dynamic conditions is a problem in capital theory.

[12] The officers of the Sunkist Growers and of the Florida Citrus Commission kindly prepared a complete record of the advertising expenditures of their organizations and made it available to us for this study.

[13] The problem of supply is an especially difficult one. As of the time of writing, a rational expectations model of orange demand and supply has been developed but not estimated. (See Muth [12] for an explanation of the rational expectations hypothesis.) The chief difficulty is that producers' expectations are affected by the current advertising policy of the cooperative. The model takes account of this aspect of the problem.

on-farm value of the crop was 18 million dollars. In recent years, the value has averaged more than 300 million dollars. Of course, it would be fantastic to ascribe the entire increase in the value of the orange crop to advertising. This would ignore many factors that were obviously important, such as the growth of the population, the rise in *per capita* incomes, the increase in the general price level, and the improvement of orange quality through better varieties and through better methods of processing and distribution. We suspect that advertising was one of the important reasons for the great expansion in the market for oranges, and our analysis is intended to get an objective measure of its effects.

To take account of the factors other than advertising which have affected the demand for oranges, we expressed demand on a *per capita* basis and regarded this as a function of the price of oranges relative to the prices of all other commodities and real *per capita* income in addition to a variable or variables which measure real *per capita* advertising expenditures. In particular, let

q_t = *per capita* marketings of oranges in boxes in year t;
p_t = the price of oranges per box deflated by the consumer price index in year t;
y_t = *per capita* disposable money income of consumers deflated by the consumer price index in year t;
a_t = *per capita* advertising expenditures for oranges by Sunkist Growers and the Florida Citrus Commission deflated by the consumer price index.

In our analysis we do not explicitly use p_t, but rather

$v_t = p_t q_t$ = the *per capita* farm value of sales deflated by the consumer price index in year t.

All of the basic data used in our analysis are presented in Table 1.

We first made several graphic analyses to help determine the nature of the demand relationship. These analyses, together with other considerations led us to adopt a demand function of the form

$$q_t = k p_t^{\alpha} y_t^{\beta} a_t^{\gamma_1} \bar{a}_t^{\gamma_2} \tag{26}$$

where k is a constant, β is the income elasticity of demand, γ_1 and γ_2 are constants to be described in a moment, and

$$\bar{a}_t = \frac{1}{10} \sum_{i=1}^{10} a_{t-i}$$

is an arithmetic average of advertising expenditures over the ten years preceding t.

An exponential function, such as (26), appears to fit the data much better than a linear function. It is theoretically more plausible, since it does not assume constant returns from advertising. It is convenient in

TABLE 1. DATA USED IN STUDY OF ORANGE ADVERTISING[1]

Crop year	Basic data						Per capita deflated series				
	Farm value of sales[2]	Consumer income[3]	Quantity sold[4]	Advertising expenditures[5]	U. S. population[6]	Consumer price index 1947–49 =100[7]	Farm value of sales v	Consumer income i	Quantity sold q	Advertising current expenditures a	Advertising average expenditures of preceding 10 years $\bar{a}$
	Mil. dol.	*Bil. dol.*	*Mil. boxes*	*Thou. dol.*	*Mil.*		*Dol.*	*Dol.*	*Boxes*	*Ct.*	*Ct.*
1907–08				7	87.9	39.0				0.0204	0.0000
08–09				26	89.7	38.0				.0763	.0020
09–10	17.7	30.2	17.1	50	91.5	39.5	0.490	836	0.187	.1383	.0097
1910–11	23.9	30.5	20.3	166	93.2	41.0	.625	798	.218	.4344	.0235
11–12	23.2	31.9	18.9	123	94.7	42.0	.583	802	.200	.3092	.0669
12–13	18.8	33.9	13.0	74	96.4	42.5	.459	827	.135	.1806	.0979
13–14	25.4	34.8	25.4	233	98.2	42.6	.607	832	.259	.5570	.1159
14–15	27.0	35.8	24.7	268	99.9	43.2	.626	830	.247	.6210	.1716
15–16	33.8	40.2	23.0	245	101.3	44.5	.750	892	.227	.5435	.2337
16–17	35.1	47.8	26.5	317	102.7	50.3	.679	925	.258	.6136	.2881
17–18	40.8	55.2	11.9	135	104.0	58.9	.666	901	.114	.2204	.3494
18–19	66.3	62.3	23.8	273	104.8	69.3	.913	858	.227	.3759	.3694
19–20	73.8	70.3	23.9	309	105.7	81.5	.857	816	.226	.3587	.3994
1920–21	58.3	61.6	32.2	565	107.6	81.7	.663	701	.299	.6427	.4214
21–22	62.8	55.4	21.6	273	109.4	73.2	.784	692	.197	.3409	.4423
22–23	59.9	64.9	31.1	585	111.1	71.8	.751	814	.280	.7334	.4454
23–24	52.2	70.4	37.0	677	113.1	73.4	.629	848	.327	.8155	.5007
24–25	81.5	70.6	28.6	515	115.0	73.6	.963	834	.249	.6085	.5266
25–26	86.1	75.8	33.4	638	116.7	76.1	.970	854	.286	.7184	.5253
26–27	96.3	76.6	38.1	748	118.3	74.8	1.088	866	.322	.8453	.5428
27–28	115.9	77.0	31.0	789	119.8	73.6	1.314	873	.259	.8948	.5660
28–29	87.6	81.2	53.8	1,210	121.2	73.1	.989	917	.444	1.3657	.6334
29–30	109.2	81.0	29.8	726	122.5	73.2	1.218	903	.243	.8096	.7324
1930–31	71.2	69.2	51.6	1,548	123.6	68.3	.843	820	.417	1.8337	.7775
31–32	57.6	55.7	46.5	962	124.5	61.6	.751	726	.373	1.2544	.8966
32–33	42.7	44.3	48.4	812	125.2	55.6	.613	636	.387	1.1665	.9879
33–34	61.0	49.9	43.0	1,005	126.0	56.6	.855	700	.341	1.4092	1.0312
34–35	68.5	54.8	58.8	1,452	126.9	58.0	.931	745	.463	1.9728	1.0906
35–36	73.5	61.8	47.7	1,001	127.7	58.7	.981	824	.374	1.3354	1.2270
36–37	87.5	69.9	47.5	988	128.5	60.3	1.129	902	.370	1.2751	1.2887
37–38	56.4	67.9	68.1	1,752	129.4	61.2	.712	857	.526	2.2123	1.3317
38–39	53.0	67.6	67.9	1,193	130.4	59.7	.681	868	.521	1.5325	1.4635
39–40	64.7	72.8	68.4	1,586	131.5	59.7	.824	927	.520	2.0202	1.4802
1940–41	93.7	82.8	77.6	1,997	132.8	60.5	1.166	1,031	.584	2.4856	1.6012
41–42	123.1	103.4	78.2	2,215	134.2	66.6	1.377	1,157	.583	2.4783	1.6664
42–43	203.1	129.9	80.4	1,311	135.9	72.3	2.067	1,322	.592	1.3343	1.7888
43–44	257.6	139.6	96.8	1,771	137.7	74.4	2.514	1,363	.703	1.7287	1.8056
44–45	273.7	150.3	101.1	1,854	139.2	76.1	2.584	1,419	.726	1.7502	1.8375
45–46	274.3	152.2	92.5	2,553	140.7	77.9	2.503	1,389	.657	2.3293	1.8153
46–47	158.5	165.7	104.8	2,747	142.8	90.8	1.222	1,278	.734	2.1186	1.9146
47–48	132.9	179.1	102.6	2,535	145.5	99.6	.917	1,236	.705	1.7493	1.9990
48–49	164.3	192.4	93.8	2,229	148.0	103.1	1.077	1,261	.634	1.4608	1.9527
49–50	222.1	195.1	98.8	2,254	150.6	101.2	1.457	1,280	.656	1.4789	1 9455
1950–51	220.5	218.5	111.2	2,453	153.1	107.4	1.341	1,329	.726	1.4918	1.8914
51–52	171.4	232.8	115.7	3,602	155.8	112.4	.979	1,329	.743	2.0569	1.7920
52–53	199.8	247.4	117.2	3,613	158.4	114.0	1.106	1,370	.740	2.0008	1.7499
53–54	235.7	254.2	122.5	3,331	161.1	115.0	1.272	1,372	.760	1.7980	1.8165
54–55	245.4	263.4	126.4	4,118	164.0	114.5	1.307	1,403	.771	2.1930	1.8235
55–56	308.0	284.1	128.0	3,736	166.8	114.9	1.607	1,482	.767	1.9494	1.8677
56–57	265.9	301.5	127.6	4,145	169.8	118.3	1.324	1,501	.751	2.0635	1.8298
57–58	320.5	311.2	104.7	4,131	172.7	122.2	1.519	1,475	.606	1.9575	1.8242
58–59	399.7	326.5	124.9	5,877	175.6	123.8	1.839	1,502	.711	2.7034	1.8451

[1] Crop years, 1907–08 and 1908–09 and World War II years, 1941–42 through 1945–46 were omitted from the analysis. [2] Data from Agricultural Estimates Division, AMS. [3] Data from Commerce Department. Since 1919–20, averages of 4 quarters; previously, averages of 2 years. [4] Agricultural Estimates Division, AMS. [5] Sunkist advertising expenditures: data from 1907–08 through 1935–36 from letter of R. Z. Eller, Calif. Fruit Growers Exchange, to J. E. Apodaca, BAE, dated March 3, 1938. Data from 1936–37 through 1957–58 from letters of F. I. Burrill, Sunkist Growers, to Paul A. Nicholson, dated Jan. 8, 1959 and April 22, 1959; data for 1958–59 from letter of F. I. Burrill to F. V. Waugh, dated Feb. 17, 1960. Florida Citrus Commission expenditures: data from 1935–36 through 1957–58 from letter of Robert Stuart, FCC, to Paul A. Nicholson, dated Jan. 9, 1959. Data for 1958–59 from letter of W. E. Black, FCC, to F. V. Waugh, dated Feb. 16, 1960. [6] U. S. Bureau of the Census, as of Jan. 1 each year. [7] Bureau of Labor Statistics. Since 1913–14, data are averages of 12 months; previously they are averages of 2 years.

computation, as we shall show later. But it is only an approximation that fits well within the range of the historical data. It cannot be safely extrapolated very far beyond that range. Thus, in spite of (26), we should not assume that the value of the orange crop would fall to zero with no advertising.

The way in which advertising expenditures are introduced deserves explanation. Advertising expenditures may be regarded as affecting demand with some sort of distributed lag; i.e., a given advertising campaign may increase the level of demand for a time, but if expenditures are not continued, demand will eventually fall to its former level. However reasonable this assumption, it gives us no clue as to the *form* of the distribution of lag. Before arriving at the present formulation, we experimented with the so-called *exponentially* distributed lag; i.e., a formulation in which present and past advertising expenditures enter the demand function as a weighted average with weights which decline as one goes back in time as a geometric series.[14] In an analysis of demand alone, the use of this form of distributed lag gave quite unreasonable results: these indicated no decline in the effectiveness of advertising with time. Several regressions were run using a number of lagged values of advertising expenditures, but no restriction of the form of the lag distribution. Interpreted as a distribution of lag, the results gave high weight to the current expenditure and, allowing for the statistical effects of introducing a large number of independent variables, a relatively constant weight to a finite number of past expenditures.[15] The present formulation was adopted as an approximation to this state of affairs.[16]

In the formulation given in (26), a permanent one per cent increase in advertising expenditures will eventually lead to a $\gamma_1 + \gamma_2$ per cent increase in demand, so that $\gamma_1 + \gamma_2$ is the *long-run* elasticity of demand with respect to advertising expenditures. In the first period, however, demand will increase by only γ_1 per cent, so that γ_1 is the shortest short-run elasticity of demand with respect to advertising expenditures. In the next period, however, demand will further increase by $\gamma_2/10$ per cent, since $\bar{a}$ will have now increased by one-tenth of one per cent; and so on, until demand has increased by a total of $\gamma_1 + \gamma_2$ per cent.[17] By using a two-parameter form of distributed lag such as that described, we were better able to approximate what appeared to be the actual distribution than we were with the one-parameter exponentially-distributed lag.

[14] A geometric weighting pattern is the discrete analogue of a continuous exponential weighting pattern.

[15] Such a distribution of lag is similar to the one used by Working [19].

[16] We have not entirely dropped the idea of using an exponentially-distributed lag; it is assumed in the rational expectations model described in footnote 13.

[17] Strictly speaking, this description is somewhat inaccurate since it involves a finite change in advertising expenditures; whereas the elasticity concept in this context is a point elasticity and therefore refers to an infinitesimal increment.

In deriving the series a_t, we were able to obtain advertising and promotion expenditures only for the two largest organized groups of growers, the Florida Citrus Commission and Sunkist Growers. While these two groups account for the bulk of marketings and of the total of grower advertising, they do not include, for example, the large promotional programs of processors, wholesalers, and retailers. Total orange advertising expenditures are unknown, but are larger than the data used in our study indicate. Thus, in a sense, our results overstate the returns from a dollar's worth of advertising. On the assumption, however, that grower expenditures are a roughly constant proportion of the total, our results do indicate the returns to growers resulting from their expenditures.

Although we had separate data on Sunkist and FCC expenditures, they were not sufficient to warrant an analysis of the effects of California advertising on returns to Florida growers, and *vice versa*.[18] Our expenditure figures were broken down into a series on "media advertising" and "promotion." But again we found that detailed analyses gave statistically unsatisfactory results. We have therefore investigated a relation between total advertising expenditures of all growers combined and total demand for the fifty-year period.

Equation (26) was not the one we actually estimated; the latter may be derived as follows: Solve (26) for p_t:

$$p_t = k^{-1/\eta} q_t^{1/\eta} y_t^{-\beta/\eta} a_t^{\gamma_1/\eta} \bar{a}_t^{\gamma_2/\eta},$$

and multiply through by q_t

$$v_t = p_t q_t = k^{-1/\eta} q_t^{1+1/\eta} y_t^{-\beta/\eta} a_t^{-\gamma_1/\eta} \bar{a}_t^{-\gamma_2/\eta}.$$

Denoting the logarithms of lower-case letters by the corresponding capital letters

$$(27) \qquad V_t = K + \left(1 + \frac{1}{\eta}\right) Q_t + \left(\frac{-\beta}{\eta}\right) Y_t + \left(\frac{-\gamma_1}{\eta}\right) A_t + \left(\frac{-\gamma_2}{\eta}\right) \overline{A}_t,$$

where $K = \log k^{-1/\eta}$. We fit (27) to the data in Table 1, excluding the World War II years, 1941-42 through 1945-46, when conditions were abnormal. We did, however, include the World War I years. Our result was

$$V_t = -2.939 - 0.390 Q_t + 0.924 Y_t + 0.233 A_t + 0.103 \overline{A}_t$$

$$(28) \qquad\qquad (\pm .198) \quad (\pm .191) \quad (\pm .125) \quad (\pm .045)$$

$$R = 0.85,$$

where the figures in parenthesis are standard errors.[19] Since we expect η to

[18] Some preliminary analysis suggests that, at least in the early years of advertising by orange growers, Florida growers benefited by the California program. But the problem of *competitive* advertising of similar products is an extremely complex one and quite difficult to analyze even though many of the basic data are at hand. Useful work in the area of competitive advertising is being done by L. G. Telser using consumer panel data and is complementary to the present investigation.

[19] It might be thought that multiplying through both sides of our demand equation

be negative and β, γ_1, and γ_2 to be positive, all coefficients have the expected signs. Furthermore, they are all significantly different from zero at the 5 per cent level. The equation is probably as reliable as many used in the U.S. Department of Agriculture in preparing its "situation and outlook" reports. In terms of the parameters of the original demand equation (26), the estimated values in (28) yield point estimates as follows:

$$\eta = -.72$$

$$\beta = 0.67$$

$$\gamma_1 = 0.17$$

$$\gamma_2 = 0.07$$

$$\gamma_1 + \gamma_2 = 0.24.$$

---

by quantity would affect our estimate of the price elasticity of demand and increase the multiple correlation. Both suppositions are false as one can easily demonstrate. Since the function considered is linear in logarithms, such a multiplication amounts to adding the same variable to both sides of the equation to be estimated. Thus let us consider estimation of the constant a and the multiple correlation under the following two alternative schemes:

(i) $$y = ax + u$$

(ii) $$y + x = (1 + a)x + u$$

where both x and y are measured as deviations from means to avoid the necessity of a constant term. In terms of moments, the least-squares estimates of a and $1 + a$ are

(iii) $$a = \frac{M_{xy}}{M_{xx}}$$

$$1 + a = \frac{M_{xy} + M_{xx}}{M_{xx}} = 1 + \frac{M_{xy}}{M_{xx}}$$

There is thus no difference whatsoever between estimates of a obtained from (i) and (ii).

Let

(iv) $$R_1^2 = 1 - \frac{M_{uu}}{M_{yy}}$$

and

(v) $$R_2^2 = 1 - \frac{M_{uu}}{M_{yy} + M_{xx} + 2M_{xy}}$$

be the squared multiple correlations obtained from (i) and (ii) respectively. Since

(vi) $$M_{yy} = a^2 M_{xx} + M_{uu}$$

by virtue of the fact that $M_{xu} = 0$, we find that

(vii) $$\frac{1 - R_1^2}{1 - R_2^2} = \frac{M_{xx} + 2aM_{xx} + a^2M_{xx} + M_{uu}}{a^2M_{xx} + M_{uu}}$$

$$= 1 + (1 + 2a)\frac{M_{xx}}{M_{yy}}.$$

Thus, R_3^2 is greater than, equal to, or less than R_1^2 according as a is greater than, equal to, or less than $-\frac{1}{2}$. Inasmuch as our estimate of $1 + a$ in (2b) is $-.39$, our estimate of a, -1.39, is well below $-\frac{1}{2}$. Thus, the multiple correlation for (28) is less than that which would have been obtained had we regressed price on quantity rather than expenditure on quantity. This is precisely opposite to what one might suspect without analysis.

The sum $\gamma_1 + \gamma_2$ may be interpreted as the *long-run* elasticity of demand with respect to advertising.[20]

Figure 3 is a graphic presentation of equation (28) which indicates how the value of the orange crop has been related to four factors: quantity of oranges sold, consumer income, current advertising expenditures, and average advertising expenditures over the 10 years 1910-59.

The first diagram in Figure 3 estimates what the farm value of oranges would have been if the quantity sold had varied from 0.2 to 0.8 boxes per capita, and if consumer income, current advertising expenditures, and the average advertising expenditures of the 10-year period had remained constant at the mean value for the whole time series. Each of the other three diagrams was drawn in a similar way, indicating how the farm value of oranges would have varied if three of the factors had been held constant at their mean values, and the other factor had varied between the values indicated in the diagram.

The first diagram is not the usual demand curve. It is shown in terms of value (that is, price times quantity) instead of in terms of price. The fact that this curve falls to the right indicates that the demand for oranges is inelastic in terms of prices to the farmer. Note that the relation of farm value to consumer income is almost a straight line. This is because the regression coefficient of value on consumer income in equation (28) is almost 1.0. The two diagrams at the bottom of the chart could be used to estimate the immediate net profit from advertising. To do this, one would need to remember that the scale for the x axis is different from the scale for the y axis. Taking account of this, the diagrams show clearly that the immediate effect of the advertising has been to increase farm value by far more than the cost of the advertising. This, however, takes no account of the long run effects of increased production. Note also that the two

[20] An earlier multiple regression analysis, not precisely equivalent to the one presented here, indicated that a linear trend was insignificant and that its presence in, or absence from, the regression did not affect the estimates of the other coefficients. A comparison of the calculated residuals from (28) with frozen concentrate consumption and with the consumption of other fruits and some vegetables failed to turn up hints of additional relationships which might have been overlooked. However, Professor Ivan M. Lee re-ran our analysis for a number of subperiods. When short subperiods are taken, the results are not statistically significant. But the following breakdown into two subperiods may be of interest:

For 1909-36,

$$V = -7.43 + \underset{(0.318)}{0.007}Q + \underset{(0.380)}{1.098}Y + \underset{(0.180)}{0.081}A + \underset{(0.050)}{0.130}\bar{A}.$$

For 1937-58,

$$V = -11.75 - \underset{(0.526)}{.865}Q + \underset{(0.498)}{1.551}Y + \underset{(0.254)}{0.313}A + \underset{(0.746)}{0.506}\bar{A}.$$

These results suggest that the demand for oranges may be becoming more inelastic with respect to price, and more elastic with respect to both consumer income and advertising. If this is correct, our analysis underestimates returns from advertising in the current period.

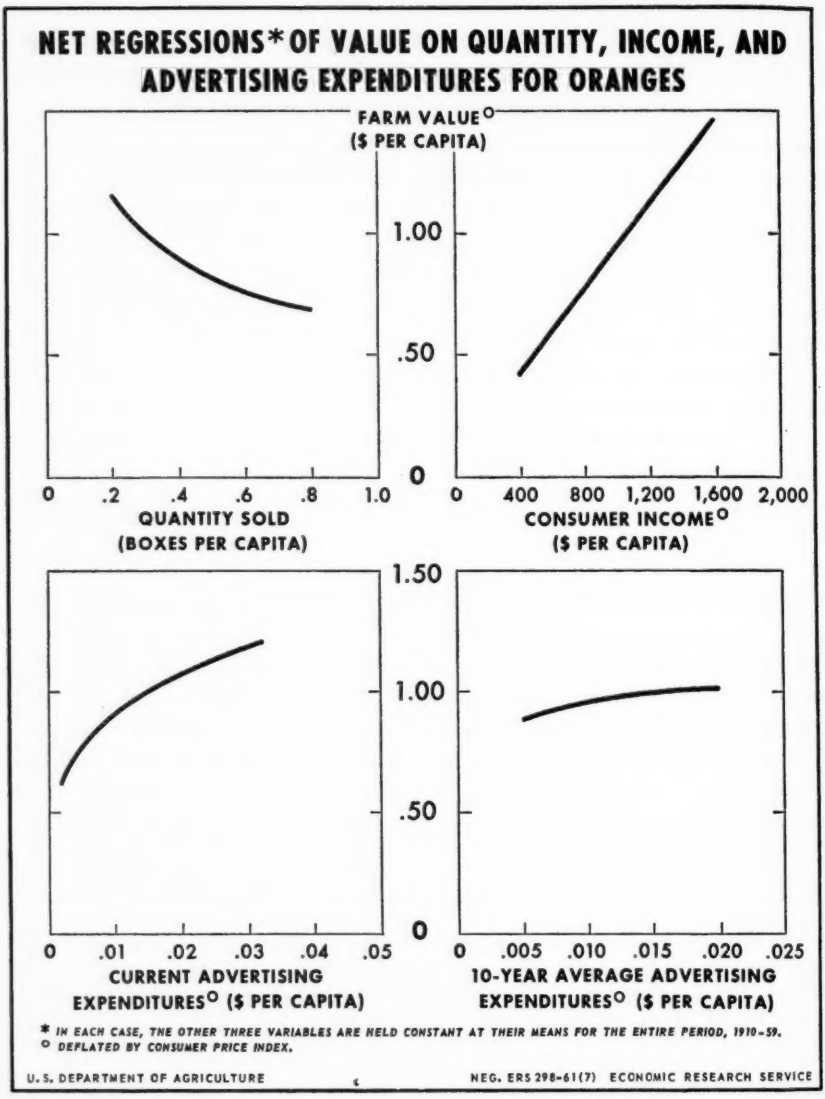
NET REGRESSIONS* OF VALUE ON QUANTITY, INCOME, AND ADVERTISING EXPENDITURES FOR ORANGES
FARM VALUE°
($ PER CAPITA)
1.00
.50
0
0 .2 .4 .6 .8 1.0
QUANTITY SOLD
(BOXES PER CAPITA)
0 400 800 1,200 1,600 2,000
CONSUMER INCOME°
($ PER CAPITA)
1.50
1.00
.50
0
0 .01 .02 .03 .04 .05
CURRENT ADVERTISING
EXPENDITURES° ($ PER CAPITA)
0 .005 .010 .015 .020 .025
10-YEAR AVERAGE ADVERTISING
EXPENDITURES° ($ PER CAPITA)
* IN EACH CASE, THE OTHER THREE VARIABLES ARE HELD CONSTANT AT THEIR MEANS FOR THE ENTIRE PERIOD, 1910-59.
° DEFLATED BY CONSUMER PRICE INDEX.
U. S. DEPARTMENT OF AGRICULTURE
NEG. ERS 298-61(7) ECONOMIC RESEARCH SERVICE

FIGURE 3

bottom diagrams indicate that marginal returns from advertising decrease rapidly as advertising expenditures increase.

We did not show residuals around the four lines in Figure 3 in order to keep the diagrams as simple as possible. However, we have studied residuals and have been unable to identify any systematic variation due to other factors. On the whole, the deviations from the statistical curves are reasonably small. Our analysis indicates that there have been two major "demand shifters"—consumer income and advertising expenditures.

V. *The Optimal Advertising Budget*

If we assume that our estimating equation (28) is valid beyond the range of observed data, then given the elasticities obtained we can compute an optimal advertising budget.

The constant-elasticity form of the demand function used in our statistical analysis enables us to restate (25) in particularly simple form. To see this, let $a = \bar{a}$ (in long-run equilibrium) and write

$$\alpha = p\frac{\partial D}{\partial a} = \frac{pq}{a}(\gamma_1 + \gamma_2) = \frac{v}{a}(\gamma_1 + \gamma_2). \tag{29}$$

Thus (25) becomes

$$\frac{\frac{v}{a}(\gamma_1 + \gamma_2)}{\epsilon - \eta}\left(\frac{1+\epsilon}{1+\sigma}\right) = 1 + \rho$$

or

$$\frac{a}{v} = \frac{\gamma_1 + \gamma_2}{(1+\rho)(\epsilon - \eta)}\left[\frac{1+\epsilon}{1+\sigma}\right]. \tag{30}$$

Consequently, our model determines optimal advertising policy in the form of a ratio of optimal advertising expenditures to sales. The optimal ratio depends on the long-run elasticity of demand with respect to advertising, the price elasticity of demand, the rate of return on alternative forms of investment, the industry supply elasticity, and the elasticity of the Σ-curves.

Our statistical analysis enables us to estimate $\gamma_1 + \gamma_2$ and η, but the remaining three parameters which enter into the determination of the optimal ratio of advertising to sales are unknown. Given the values of $\gamma_1 + \gamma_2$ and η obtained in our statistical analysis, however, it is possible to express the optimal ratio of advertising to sales as a function of σ, ε, and ρ.

When either (a) there are no external economies or diseconomies to the industry, or (b) there are, but these go unrecognized by the cooperative, then the optimal advertising ratio is determined by setting $\sigma = \varepsilon$ in (30). In this case the term in square brackets becomes unity and the optimal ratio is a function of ε and ρ. Values of this function for various combinations of ε and ρ are given in Table 2.

When interpreting Table 2, it should be remembered: (a) that the elasticity of supply referred to is the long-run elasticity, and (b) that the economically optimal ratio is only an upper limit to the ratio of advertising expenditures to sales which a majority of the group will continue to support. A rather wide range of rates of return on alternative forms of investment has been given partly in order to allow for this effect. It should be noted that, for any given elasticity of supply, the optimal ratio of adver-

TABLE 2. OPTIMAL RATIOS OF ADVERTISING TO DOLLAR SALES OF ORANGES WHEN EXTERNAL ECONOMIES OR DISECONOMIES ARE UNANTICIPATED OR ABSENT, FOR VARIOUS COMBINATIONS OF RATES OF RETURN ON ALTERNATIVE FORMS OF INVESTMENT, ρ, AND INDUSTRY SUPPLY ELASTICITIES, ϵ

$\epsilon=\sigma$	ρ			
	0	.05	.10	.40
0.1	0.293	0.279	0.267	0.209
0.4	.234	.223	.212	.167
1.0	.140	.133	.127	.100
2.0	.088	.084	.080	.063
5.0	.041	.039	.037	.029
10.0	.023	.022	.021	.016
∞	0	0	0	0

tising expenditure to sales is not very sensitive to the rate of return on alternative forms of investment. On the other hand, the optimal ratio is quite sensitive to the elasticity of supply; extremely high ratios are obtained for low supply elasticities, and the ratio drops off sharply at first but becomes more insensitive to the supply elasticity when the latter is large.

When external economies or diseconomies exist and are recognized by producers as a group, the calculations are not so simple. Since the optimal ratio is insensitive to the rate of return on alternative forms of investment, we may neglect the latter by assuming it to be zero. Thus the optimal ratio is a function of the elasticity of the Σ-curves, σ, and the industry supply elasticity, ϵ. When ϵ is positive, there are a predominance of external diseconomies. Table 3 gives optimal advertising ratios for various combinations of σ and positive ϵ, Table 4 for various combinations of σ and negative ϵ. Values of ρ different from zero imply a slight downward adjustment of the figures given.

Note that, as in the case in which external economies or diseconomies

TABLE 3. OPTIMAL RATIOS OF ADVERTISING TO DOLLAR SALES OF ORANGES WITH EXTERNAL DISECONOMIES OF SCALE, FOR VARIOUS COMBINATIONS OF ϵ AND σ; $\rho=0$

σ	ϵ				
	1.0	2.0	4.0	8.0	∞
0.1	0.255	0.240	0.232	0.229	0.218
0.4	.200	.189	.182	.180	.171
1.0	.140[1]	.132	.128	.126	.120
2.0	.093	.088[1]	.085	.084	.080
5.0	.047	.044	.043	.042	.040
10.0	.025	.024	.024	.023	.022
∞	0	0	0	0	0

[1] These entries correspond to entries in the second column of Table 2 which are computed on the assumption that $\sigma=\epsilon$.

TABLE 4. OPTIMAL RATIOS OF ADVERTISING TO DOLLAR SALES OF ORANGES WITH EXTERNAL ECONOMIES OF SCALE, FOR VARIOUS COMBINATIONS OF ϵ AND σ; $\rho=0$

σ	ϵ					
	-1.0	-1.5	-2.0	-4.0	-8.0	$-\infty$
0.1	0	0.140	0.171	0.199	0.210	0.218
0.4	0	.110	.134	.156	.165	.171
1.0	0	.077	.094	.110	.116	.120
2.0	0	.051	.063	.073	.077	.080
5.0	0	.026	.031	.037	.039	.040
10.0	0	.014	.017	.020	.021	.022
∞	0	0	0	0	0	0

are absent or neglected, the optimal advertising ratio is sensitive to the elasticity of the Σ-curve. It is virtually unaffected by the industry supply elasticity when there are external diseconomies. This is not the case, however, when there are external economies: When ϵ is close to -1, small changes in ϵ may make substantial difference in the optimal ratio. In the stability argument in the first section of this paper we deduced that ϵ could not exceed the price elasticity of demand algebraically; thus, we need not consider values of ϵ less than 0.72 in absolute value. Reference to (30), moreover, shows that the ratio is negative when ϵ is between $-.72$ and -1.0. This is, of course, impossible and we conclude that only values of ϵ greater than 1.0 in absolute value need be considered. When $\epsilon = -1.0$, it clearly never pays to advertise. The reason is simply that shifting the demand curve can have no effect whatsoever on gross revenues in these circumstances. As the industry supply elasticity increases in absolute value, however, the optimal ratio increases rapidly at first, then more slowly.

VI. Some Conclusions

The analysis and results presented in this paper could be used in either of two quite different ways: First, the economist could use the actual ratio of advertising to sales to get a rough idea of what the two grower groups believe about the long-run elasticities of the particular expenses curves and the industry supply curve. Second, if growers can place *a priori* bounds on these elasticities, then our analysis would enable them to judge whether an increased advertising budget would be profitable or unprofitable to them.

Organized orange growers are now spending about 1½ percent of their gross income for advertising and promotion. Our equation (28) indicates that *if orange production remained constant* an added dollar of advertising would raise the gross returns to orange producers by over 20 dollars. Thus, if orange production were held constant, the orange growers would obviously find it profitable to spend more for advertising. But when supplies

are uncontrolled, it is impossible to judge the long-run effects of advertising without taking account of such matters as the long-run elasticity of supply and external economies or diseconomies.

Disregarding for the moment potential economies or diseconomies, an increased advertising budget would apparently be profitable to growers unless the long-run elasticity of supply is very high, perhaps in excess of 10. While we do not have a reliable estimate of the elasticity of supply of oranges, it is doubtless high compared with most agricultural commodities. Suitable land has been widely available; many have been eager to start a new grove or enlarge an old one; and labor and capital have been generally available whenever there was a prospect of favorable prices. Still, an elasticity of 10 seems out of line.

But one cannot disregard the possibility of external economies. If these economies are very marked (say $-1.5 < \varepsilon < -1.0$), the elasticity of the particular expenses curve can be quite low and yield an optimal ratio of as little as 1½ or 2 per cent of gross income. In the decade 1910-20, orange consumption averaged 21 million boxes; the average deflated price of oranges during the same period was $3.36 per box. In recent years, 1950-59, orange consumption has averaged nearly 120 million boxes; the average deflated price during the same period has been $1.70 per box. To get a rough idea of the extent of external economies, we may compute an arc elasticity for these two points; it is -2.1. If growers take the long-run industry elasticity of supply to be about -2, and the elasticity of particular expenses to be between 5 and 10, their present advertising expenditures would appear to be close to optimal.[21] Needless to say, these results are highly conjectural. More specific conclusions could be drawn if we had explicit knowledge of the elasticities of particular expenses and industry supply.

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AGRICULTURE AND TECHNICAL CHANGE

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Introduction

IN THIS paper it is proposed to discuss the economic effects of technical progress in agriculture by means of a simple two product model of an economy. Such an analysis is obviously a gross simplification but sometimes a two commodity analysis enables us to reach some worthwhile conclusions about the real world. While one of the assumptions of the model is varied in a later part of the paper, no attempt is made to provide a rigorous extension of the argument to more than two goods.

It has been generally agreed among agricultural economists that many forms of technical change in agriculture—in particular so-called "output increasing" innovations[1]—reduce farm income below the levels which would otherwise prevail. This conclusion is derived from empirical studies showing that the aggregate demand elasticity for farm products as a whole is less than unity. This automatically means that producers get less for producing more. However, as far as I am aware, no attempt has been made so far to make allowance for any supply or income reactions to unilateral technical change in agriculture. This is probably the result of the assumption—often implicit—that supply responses are relatively less important. As recent econometric work has suggested that supply responses may be more significant than usually assumed, it seems desirable to incorporate such supply (and income) reactions into the analysis of the economic effects of unilateral technical change. It will be suggested below that an inelastic demand may be not only a necessary but also a sufficient condition for an absolute decline in farm incomes. In other words that, even if the supply elasticity is large and positive—say greater than unity—an inelastic demand may still lead to lower farm incomes after technical progress than before. (The supply reactions considered are those affecting factors of production, not entrepreneurs.)

It is proposed to use the familiar tools of production possibility (or transformation) curves and indifference curves. In the text a diagrammatic presentation of the argument is given. Certain equations necessary for

* I am greatly indebted to Dr. I. F. Pearce and Professor T. W. Swan for showing me how to attack problems of this kind—and for pointing out numerous errors in an earlier draft. I have also benefited from comments of the reviewers and from a correspondence with Professor Glenn L. Johnson on this topic.

[1] The writer is doubtful of the value of the distinction between output increasing and cost reducing innovations. For surely a "cost reducing" innovation in an industry —by increasing the profitability of that particular industry—will encourage a consequent expansion of output in it.

the discussion are derived in the Appendix. In Section I the basic model will be presented; in Section II the basic model is extended to allow for international trade; in Section III the applicability of some of the assumptions to the real world is discussed and some of the limitations of the analysis are outlined.

I. *The Basic Model*

We assume that:

(i) There are two goods in the economy—*A* (agricultural) and *N* (non-agricultural).

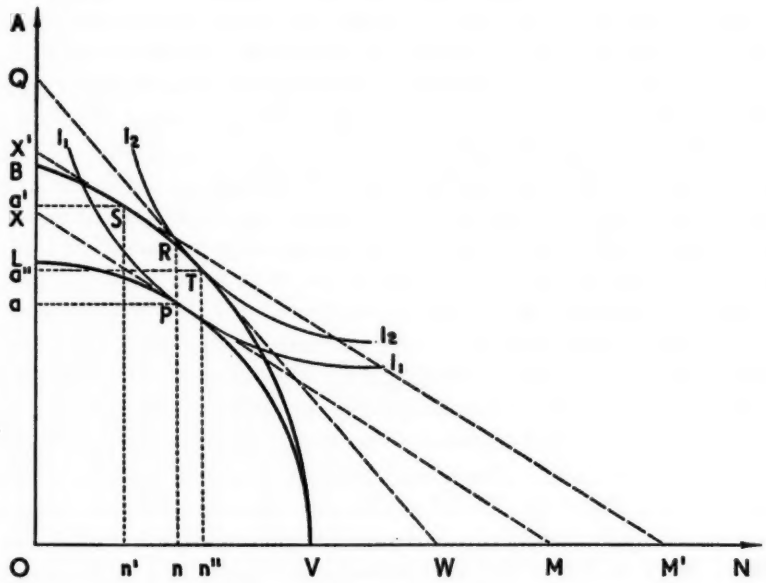

FIGURE 1

(ii) Technical progress takes place in the production of *A* and not of *N*.

(iii) Technical change takes the form of neutral technical progress in the Hicksian sense (i.e. it is neither capital nor labour saving).

(iv) The economy is closed—i.e. no exports or imports of either product.

(v) The analysis is in static terms—it discusses the equilibrium position before and after a technical advance in the production of *A* and ignores problems of adjustment in the interim.

Prior to the technical change, let the boundary of production possibilities open to the economy be represented by the line *LPV* in Figure 1. Given the indifference curve I_1, the optimum output combination is at point *P*—when *On* units of *N* and *Oa* units of *A* are produced. The relative price of *A* in terms of units of *N* is given by the slope of the price

line *XPM*. With technical progress in the production of *A*, let the new transformation curve (i.e. boundary of the production possibilities) be represented by the line *BSRTV*. The line *BSRTV* possesses the following properties:

(a) It coincides with the pre-improvement transformation curve *LPV* at point *V*—when all resources are devoted to the production of *N*.

(b) At any other point *R* on the new transformation curve, the slope of the new curve is greater than the slope at the corresponding point *P* on the old transformation curve. Point *R* on the new curve "corresponds" to *P* on the old, in the sense that there has been—as yet—no change in the resources devoted to the production of either *A* or *N*.

Why do we draw the new transformation curve in this way—or what does this mean in terms of economics? Our postulate of Hicksian neutral technical progress means that if the original production function for good *A* is given by $A = f(x_1, x_2, \ldots\ldots x_n)$, then the production function after technical progress can be written $A = \lambda f(x_1, x_2 \ldots\ldots x_n)$ where $\lambda > 1$. To put it differently, the marginal products of all factors used in the production of *A* are increased by an equal fraction (at the old input-mix). This implies that, unless product prices change, the production of *N* will decline after neutral technical progress in *A*. In terms of transformation curves, the marginal rate of transformation of *N* for *A* (i.e. dA/dN) will be increased (numerically) by neutral technical progress.

When the community is confronted with the new set of production possibilities indicated by the boundary line *BSRTV*, the optimum position moves from point *P* to point *T*—where *On''* units of *N* and *Oa''* units of *A* will be produced. This movement can be subdivided—in a manner somewhat analogous to the Hicks-Slutsky theorem—into an expansion effect (i.e. from *P* to *S*) and a substitution effect (from *S* to *T*).[2] The expansion effect shown in Figure 1 consists of the changes in the output of *A* and *N* resulting from technical progress—at the "old" product price ratios. *S* is situated at the point of tangency of the new transformation curve *BSRTV* and a price line parallel to *XPM* (namely *X'SM'*).

The expansion effect can be defined either in terms of its influence on the *output* of *A* and *N* or in terms of its influence on the *volume of resources* used for production of *A* and *N*. As shown in Figure 1 the expansion effect leads to an increase in the volume of resources used for *A* (and in the output of *A*) and a decrease in the output of, and resource use in *N*. The size of the expansion effect will depend on the magnitude of the distance between *R* and *P* and on the degree of curvature of the trans-

[2] This subdivision is purely a conceptual device. It is not necessarily suggested that the output of *A* would, in practice, first rise from *Oa* units to *Oa'* units and then decline to *Oa''* units.

formation curve between R and S. In economic terms these correspond to the initial rise in output resulting from an innovation (prior to any shift in resources) and the elasticity of supply of A respectively.

The relative increase in the output of A will affect its (relative) price. This gives rise to the substitution effect. Unlike the Hicks-Slutsky substitution effect, the size of this shift will depend not only on the elasticity of demand but also on the elasticity of supply. This can be seen from Figure 1, as the magnitude of the movement from S to T will depend on the degree of curvature of the indifference and transformation curves. It can also be seen in Figure 1 that the substitution effect will lead to a reduction in the resources devoted to A-production.

It may be of interest, in the first place, to examine the combined effect of the expansion and substitution effects on the volume of resources employed in the production of A and N respectively. The new equilibrium point T, as drawn in Figure 1, implies that some resources have been diverted from the production of A to the production of N. However it is not difficult to imagine that the indifference curves could be re-drawn so that the new equilibrium point T is to the left of R rather than to the right of it as shown in Figure 1. Changes in the volume of resources employed are best measured in terms of changes in the supply of N. Since there has been no technical change in the conditions of production for N a change in the supply of N implies a similar change in the volume of resources used in the production of N. It is shown in the Appendix that the change in the supply of N (dS_N) resulting from a unit change in technique ($d\lambda$) is given by the following equation:

$$\text{(i)} \qquad \frac{dS_N}{d\lambda} = -\, g_A \cdot \frac{pS_A}{\lambda}\left(\frac{1 - E_A}{C_A - E_A - g_A}\right)$$

where:

p is the price of A

S_A is the amount of A supplied;

g_A is the elasticity of supply of A; i.e. $\partial(\log S_A)/\partial(\log p)$

λ is the technical progress parameter (measured in terms of output; but it can be conceived of in terms of any units we choose as convenient, e.g. hybrid corn acres, tractor numbers etc.).

C_A is the marginal propensity to consume A; i.e. $p(\partial D_A/\partial y)$ where D_A is the quantity of A demanded and y is income.

E_A is the elasticity of demand for A; i.e. $-\partial(\log D_A)/\partial(\log p)$.

A unilateral technical change in agriculture will lead to a resource flow away from agriculture when $dS_N/d\lambda$ in (i) is positive. As g_A, p, S_A and λ are all positive, this amounts to ascertaining when the expression in

brackets, namely $(1 - E_A)/(C_A - E_A - g_A)$ becomes negative. The denominator of this expression (i.e. $C_A - E_A - g_A$), must be negative, since C_A is contained in E_A and must therefore be numerically smaller, whilst E_A is positive and g_A is also positive or, according to some writers, near to zero.[3] Thus $dS_N/d\lambda$ will be positive when $1 - E_A$ is positive. In other words resources will move away from agriculture when the elasticity of demand for agricultural products is less than unity (and vice versa). In terms of our terminology the size of the substitution effect then exceeds that of the expansion effect.[4]

What is the effect of neutral technical progress in the production of A on the gross revenue of the producers? As shown in Figure 1 a neutral innovation will lead to a reduction in the price of A (if we ignore the possibility that N is an inferior good). However it cannot be shown diagrammatically whether the reduction in price is sufficiently great to offset the increase in output. It is shown in the Appendix that the percentage change in the gross revenue of the producers of A is given by the following equation:

$$\text{(ii)} \qquad \frac{dG_A}{G_A} = \frac{d\lambda}{\lambda}(g_A + 1)\left(\frac{1 - E_A}{C_A - E_A - g_A}\right)$$

where G_A is the gross revenue of producers of A (i.e. $G_A = pS_A$), and the other symbols have the same meaning as in equation (i).

A unilateral technical change in agriculture will lead to a reduction in

[3] Slutsky's "Fundamental Equation of Value Theory"—to use Hicks' description—can be restated as follows in the above notation:

$$E_A = C_A + \left(1 - \frac{pS_A}{y}\right)\tau_A$$

where τ_A is the elasticity of substitution, which is positive. As part of the community's income is spent on good N, $1 - (pS_A/y) > 0$. Hence $E_A > 0$ (unless A is an inferior good, which would make $C_A < 0$) and $E_A > C_A$.

C_A—the marginal propensity to consume agricultural products—is simply the income elasticity multiplied by the proportion of income spent on farm products. Thus if the income elasticity for farm products as a whole was 0.25 at the beginning of the fifties in the U.S., as T. W. Schultz has suggested (cf. *The Economic Organisation of Agriculture*, McGraw-Hill. New York, 1953, p. 71), and if the proportion of income spent on farm products equalled, say, 10 per cent, then the marginal propensity to consume agricultural products in the U.S. at the beginning of the fifties would have equalled 0.025. The supply elasticity concept used above is the normal one for general equilibrium analysis—which assumes that factor endowment is constant and that the supply of factors can only vary when factor prices vary. It differs from the supply elasticity concept sometimes encountered in partial equilibrium theory which assumes (wrongly) that factor prices are constant.

[4] In terms of resource movements the expansion effect is given by $-g_A\,(pS_A/\lambda)$, and the substitution effect by

$$-g_A \frac{pS_A}{\lambda}\left(\frac{1 + g_A - C_A}{C_A - E_A - g_A}\right).$$

gross farm income when (ii) becomes negative. As λ and $g_A + 1$ are both positive this amounts to ascertaining when the second expression in brackets becomes negative. As shown earlier this will be negative when $1 - E_A$ is positive. In other words, if the elasticity of demand for A is less than unity, neutral, technical change (in A-production) will lead to a reduction in gross revenue.

Assuming linear and homogeneous production functions for A and N, Professor T. W. Swan has shown that a similar condition holds for net revenue. "Net revenue" in this context is identified with the return to a fixed factor (x_2) when production of A is defined as being a function of the quantity of a mobile factor (x_1) employed and of the technical progress parameter λ. The proof is again given in the Appendix. The equation giving the percentage change in the net revenue of producers of A is:

$$\text{(iii)} \qquad \frac{dR_A}{R_A} = \frac{d\lambda}{\lambda}\left(1 + \frac{g_A}{\theta_A}\right)\left(\frac{1 - E_A}{C_A - E_A - g_A}\right)$$

where: R_A is the net revenue of the producers of A
θ_A is the elasticity of substitution of the production function for A.

Since $\theta_A > 0$ (except in extreme cases of fixed factor proportions), it follows that—given our assumptions—an inelastic demand is a necessary and sufficient condition for a decline in net revenue. In the particular case of a linear and homogeneous Cobb-Douglas production function, equation (iii) becomes identical with (ii) since the elasticity of substitution then becomes unity.[5]

This may seem a strange conclusion, since it was argued earlier that the size of the expansion and substitution effects depended, in part, on supply effects. Broadly speaking, the reason for this state of affairs is that the supply reactions operating through the expansion and substitution effects act in opposite directions and thus tend to counteract one an-

[5] The writer has not been able to show that an inelastic demand is a sufficient condition for a decline in net revenue (after unilateral technical change) for *any* type of production function. However it is certain that the above holds for some production functions which are not homogeneous. Consider, for example, a two-good model of the economy with production functions of the form

$$A = f(x_A) \qquad \text{and} \qquad N = f'(x_N)$$

where x_A and x_N are quantities of a single factor used for the production of A and N. This type of function has been used on occasions to illustrate some properties of an economic system. (See for instance Herbert A. Simon "Productivity and the Urban-Rural Population Balance," *Econometrica*, 15:31-42, Jan. 1947, and the references cited there.) It can be shown that for such functions an inelastic demand is again a necessary and sufficient condition for a decline in net revenue after unilateral technical change.

other. The expansion effect draws resources away from N, since the marginal product of the factors employed in the production of A has risen. On the other hand the substitution effect draws resources towards the production of N, since the relative increase in the output of A reduces its price.

II. *International Trade*

If we drop the assumption of a closed economy and postulate two countries, I (the innovating country) and O (the other country), equations (ii) and (iii) can be restated thus:

$$\text{(iv)} \qquad \frac{dG_{AI}}{G_{AI}} = \frac{d\lambda}{\lambda}(g_{AI}+1)\left[1+\frac{\frac{S_{AI}}{S_{AW}}(1+g_{AI}-C_{AW})}{C_{AW}-E_{AW}-g_{AW}}\right]$$

$$\text{(iv')} \qquad \frac{dR_{AI}}{R_{AI}} = \frac{d\lambda}{\lambda}\left(\frac{g_{AI}}{\theta_{AI}}+1\right)\left[1+\frac{\frac{S_{AI}}{S_{AW}}(1+g_{AI}-C_{AW})}{C_{AW}-E_{AW}-g_{AW}}\right]$$

Here the second subscripts identify the country to which the elasticity or propensity relates. Thus g_{AI} is the elasticity of supply of A from country I. The subscript W refers to $I+O$, or to world elasticities. In the derivation of these equations—given in the Appendix—it was assumed that any deficit in the balance of trade between countries I and O will be financed, if necessary, by capital transfers, gifts etc. (This assumption was made mainly to simplify the analysis. In addition, there is a fairly voluminous literature—briefly referred to below—dealing with the effects of technical change in one country on its net income, terms of trade, and balance of payments.)

What are the conditions under which the net revenue of producers of A in the innovating country will be lower after technical progress than before? If we regard

$$\left(1-\frac{S_{AI}}{S_{AW}}\right)C_{AW}$$

—a fraction of the world marginal propensity to consume farm products—as being sufficiently small to be ignored for practical purposes, the condition is that the elasticity of demand confronting the producers of A in country I (i.e. E_{AI}) is less than unity.[6] It should be stressed that this is a

[6] $\frac{dG_{AI}}{G_{AI}}$ and $\frac{dR_{AI}}{R_{AI}}$ will be negative when

$$1+\frac{\frac{S_{AI}}{S_{AW}}(1+g_{AI}-C_{AW})}{C_{AW}-E_{AW}-g_{AW}}<0.$$

fairly stringent requirement. E_{AI} depends on the world elasticity of demand for A, country O's supply elasticity and the proportion of the world's supply of A which is produced by country I. Even with fairly low values of E_{AW} and g_{AO}, the elasticity of demand for A confronting producers in country I may be above unity, if country I's proportion of the world's supply (i.e. S_{AI}/S_{AW}) is low enough. Thus if E_{AW} equals 0.3 and g_{AO} equals 0.2—to use two values which have been mentioned by econometricians for all farm products for the United States—E_{AI} will be above unity if S_{AI}/S_{AW} falls below 41.6 per cent. (However, if allowance is made for transport costs, tariffs and quantitative restrictions in international trade, the critical percentage would be reduced.)

The introduction of international trade opens up the theoretical possibility of "immiserising growth"—namely that technical progress in country I may actually lead to a reduction in the total volume of goods available for consumption in that country. (This case differs from the one discussed above where the revenue of producers of A in country I was considered without reference to the income of producers of N in country I.) The conditions for immiserising growth have been analysed by Professor H. G. Johnson and J. Bhagwati.[7] The possibility of immiserising growth arises only when either or both the following conditions are fulfilled: (i)

Ignoring $\left(1 - \frac{S_{AI}}{S_{AW}}\right)C_{AW}$ this implies that

$$\frac{S_{AI}}{S_{AW}}(1 + g_{AI}) > E_{AW} + g_{AW}.$$

As it can be shown that

$$g_{AW} = \frac{S_{AI}g_{AI} + S_{AO}g_{AO}}{S_{AW}}$$

this reduces to

$$1 > \frac{S_{AW}E_{AW} + S_{AO}g_{AO}}{S_{AI}} = E_{AI}.$$

Two comments should be made here:

(a) The elasticities used in this section are total logarithmic differentials with respect to price and may differ from the more normal partials. They are used here partly as an expository device, showing that an inelastic world demand does not necessarily imply an inelastic demand confronting producers in a single country.

(b) The writer suspects that the residual term

$$\left(1 - \frac{S_{AI}}{S_{AW}}\right)C_{AW}$$

appears in the above equations because of the simplifying assumption that the balance of trade (after technical change) need not balance. This may, in effect, implicitly introduce certain income changes.

[7] Harry G. Johnson, *International Trade and Economic Growth*, George Allen and Unwin Ltd. 1958, ch. III and V.

Jagdish Bhagwati, "Immiserising Growth: A Geometrical Note," Rev. Econ. Studies, 25:201-05 (June 1958).

the demand for country *I*'s export good *A* is inelastic and (ii) technical progress actually reduces the output of good *N* in country *I*.

Using Figure I it is possible to show that "100% parity" plus gifts of surpluses to other countries could lead to "immiserising growth." Suppose that prior to technical change the equilibrium position is at *P* and that the government guarantees producers of *A* the relative price indicated by *XPM*. After (neutral) technical progress *Oa'* units of *A* will be produced and *On'* units of *N*. To maintain this relative price ratio the government will have to purchase more than *a'a* units of good *A*. If this surplus is given away the economy will be left with a smaller volume of goods (i.e. both of *A* and *N*) than before the introduction of the innovation.

Economically what this means is that a neutral innovation in *A* (and also some types of biassed innovations) increases the marginal productivity of factors used in the production of *A*; there will therefore be a tendency for resources to move from *N*-production to *A*-production—unless the price of *A* is allowed to fall relative to the price of *N*. Hence if the price of *A* is maintained at the old level and the surplus of *A* is bought by the government and given away abroad, the community will have a smaller volume of goods available for consumption than before.

III. *Some Limitations*

Neutral technical progress

Historically, changes in the agricultural production process have often taken the form of the substitution of purchased inputs from the industrial sector of the economy (e.g. fertiliser, machinery, fuel, pesticides etc.) for farm labour or farm produced inputs. As a result of this trend it has sometimes been argued that technical progress in agriculture is not neutral in the sense defined above. However this type of evidence is by no means conclusive proof that technical change in agriculture has been, in the aggregate, relatively labour saving.

At any moment of time the optimum combination of resources for the production of a commodity will depend on two factors—the shape of the relevant production function and relative factor and product price ratios. Over time, changes in technology in agriculture will affect the shape of the production function, whilst changing technology in all sectors of the economy, changes in tastes etc. will affect factor and product price ratios. Hence the movement of resource combinations in agriculture which is observed over time might be regarded as an amalgam of adjustments to changing technology in agriculture and changing relative factor and product price ratios. If labour has become relatively more expensive over time, one would expect some substitution of other factors of production

for labour. While one cannot be dogmatic about the nature of innovation, there would seem to be no a priori reason why technical change is likely to be more labour saving than capital saving.[8]

Nevertheless it is not necessarily realistic to assume that technical progress is neutral. Bhagwati has pointed to one method of analysing the effects of biassed technical progress.[9] For biassed technical progress can be regarded as a compound of neutral technical progress and a relative increase in the supply of that factor which the innovation has "saved." If we make use of a theorem first established by T. M. Rybczynski we can at least indicate the differences between biassed and neutral technical progress. T. M. Rybczynski has shown that in a two-factor, two-good economy an increase in the supply of one factor will result—at unchanged product prices—in an absolute reduction in the output of that good which uses the increased factor relatively less intensively.[10] (This proof is dependent on linear and homogeneous production functions and that the increase in factor supplies does not reverse the industries' factor intensities.) In other words, if *A* is the labour-intensive industry which adopts a labour-saving innovation, the output of *N* will decline—at unchanged product prices (i.e. the expansion effect will be numerically greater than for a neutral innovation). But if *A* adopts a capital-saving innovation, the output of *N* will not necessarily increase, as the innovation has indirectly increased the marginal product of both factors in *A*. Bias in technical progress will show itself through what has been labelled above, the expansion effect, and will leave the substitution effect unaltered.

[8] For a more detailed discussion see W. E. G. Salter, *Productivity and Technical Change*, Mono. No. 6, Univ. of Cambridge, Dept. of Applied Economics, Cambridge Univ. Press, 1959, ch. II and III, especially pp. 42-44.

This question is also of relevance in other connections. Barton has suggested that approximately half the increase in the output of U.S. agriculture since 1940 can be attributed to farm mechanisation and to the greater use of commercial fertiliser on farms ("Technological Change, Food Needs, and Aggregate Resource Adjustment," *J. Farm Econ.*, 40:1429-30, Dec. 1958). Furthermore Griliches and others have shown that a large proportion of the change in fertiliser and machinery purchases can be "explained" by price reactions (cf. *J. Farm Econ.*, 41:309-49, May 1959). In as far as such price changes are the result of technical progress in industries supplying agriculture, the latter should be "credited" with part of the achievements of U.S. agriculture. A recognition of the significance of the performance of these industries may be important in a number of contexts—for instance in determining questions of priority in development programmes, or in ascertaining the reasons for the relative progress or stagnation of agriculture in different countries.

[9] Jagdish Bhagwati, "Growth, Terms of Trade and Comparative Advantage," *Economia Internazionale*, 12:406, Aug. 1959.

[10] T. M. Rybczynski, "Factor Endowment and Relative Factor Prices," *Economica*, vol. 22, No. 88 (Nov. 1955) pp. 336-41. For a mathematical proof see Jagdish Bhagwati, *op. cit.*, p. 405. For a detailed geometrical treatment of the effects of biassed technical progress on output in different industries, see Ronald Finlay and Harry Grubert, "Factor Intensities, Technological Progress and the Terms of Trade," Oxford Economic Papers, vol. II, No. 1 (Feb. 1959) pp. 111-21.

The concept of elasticity

In a recent paper, Glenn L. Johnson has cast doubt on the usefulness of the general concept of elasticity—and in particular on the concept of supply elasticity, citing Samuelson's *Foundations of Economic Analysis* in support of his position.[11] As I have made extensive use of various elasticity concepts above, it would seem desirable to make some comments on this issue. Samuelson uses two arguments against these "dimensionless expressions called elasticity coefficients": (a) ". . . most of the 'laws of economics' are qualitative and ordinal rather than quantitative, and where such are concerned the problem of dimensions is of no concern";[12] (b) "while elasticity expressions are invariant under changes of scale, they are not invariant under changes of origin. Since there are no natural zeros from which we measure economic magnitudes, the elasticity expressions can be seen to be essentially arbitrary."[13]

This is not the place to discuss these general questions in any detail. The important test, it seems to me, is whether elasticities represent parameters with a sufficient degree of permanence to make them useful for prediction or interpretation. The lack of invariance with respect to change of origin can be allowed for if and when the origin is changed for a particular purpose. The writer has used elasticities in presenting the relevant equations in the text, because a great deal of empirical work has been done on the estimation of demand and income elasticities for farm products and some promising attempts have been made recently to estimate supply elasticities. Granted that there are numerous statistical and theoretical problems connected with these endeavours, we have probably obtained valuable guides of the order of magnitude of the different coefficients. These estimates should make it possible to assess more accurately the quantitative effect of technical progress and other economic changes. Furthermore, while the above analysis has been couched in terms of elasticities, these are by no means necessary to the argument. In other words, the demand, supply and income reactions to unilateral technical change can be stated in terms of non-logarithmic derivatives instead of elasticities, if this should be regarded as preferable. While this would probably meet the objections raised by Professor Samuelson, those advanced by Professor Johnson would seem to be in a somewhat different category.

Professor Johnson's objections to the concept of the elasticity of supply

[11] Glenn L. Johnson, "The State of Agricultural Supply Analysis," *J. Farm Econ.*, 42:444-49, May 1960.

[12] Paul A. Samuelson, *Foundations of Economic Analysis*, Harvard Economic Studies No. 80, Harvard Univ. Press, Cambridge, Mass., 1955, p. 125.

[13] Paul A. Samuelson, *op. cit.*, p. 125.

are that the existence of fixed assets—in the "short" or "medium" run—leads to discontinuities and to differential supply responses for expansions and contractions—at least in the case of individual firms.[14] These are not, it seems to me, objections to the *concept* of a supply elasticity. It may be that supply is very inelastic (or even perfectly inelastic) in the short run or it may be true that price increases call forth proportionately greater supply response than price declines of the same magnitude. This could be allowed for within the general analysis presented above. In fact the distinction between an expansion and a substitution effect may make it easier to allow for such reactions. If one accepts assymetrical supply elasticities (e.g. because of the "fixed assets" theory) the substitution effect on the supply side will not compensate for the initial inflow of resources (classified under the expansion effect). Under these conditions the elasticity of demand for the product of the innovating sector may need to be greater than unity to avoid a decline in net incomes to producers in that sector.

Comparative statics

The basic objection to the method of comparative statics is that the relevant equilibria positions posited by this method are not likely to be achieved because of prior disturbances. Also, as Brandow has pointed out, it is true that, treating the problem of technical change as an episodic rather than a continuing one could obscure certain elements of a process of continuous adjustment to technical change.[15] As a partial defence of my position I would submit the following considerations:

(a) Technical improvements in agriculture, by and large, require many years to be adopted by a multitude of individual producers. Furthermore there are good economic reasons why, even if an industry should consist of a small number of firms, a considerable lag in the adoption of new techniques should be experienced.[16]

(b) The method of comparative statics enables us to analyse the forces at work during the long term process of adjustment to technical change. In other words it focuses attention on the demand, supply and income reactions to unilateral technical change. Such a method of analysis would therefore appear to be a necessary prerequisite to a more thorough going dynamic analysis, which will probably involve the empirical estimation of a series of parameters in a complicated system of mixed difference differential equations.

[14] Glenn L. Johnson, *op. cit.*, p. 449.

[15] G. E. Brandow, "Discussion: Implications of Changing Technology and Incomes in Agriculture," *J. Farm Econ.*, 40:1594 (Dec. 1958).

[16] Cf. W. E. G. Salter, *op. cit.*, ch. IV.

Other limitations

No attempt will be made here to provide a rigorous extension of the argument to the situation where technical progress occurs in *N* as well as in *A*. Using one type of production function Herbert Simon has shown that equal percentage increases in efficiency in *A* and *N* will lead to a decrease in the quantity of resources employed in *A*—given the assumption that the income elasticity of demand for *A* is greater than that for *N*.[17] An alternative proof can be given using the more general production functions implied by equation (i) above. However, as has been suggested by a number of authors, technical change outside agriculture often leads to the development of industrially produced substitutes for agricultural products or to the substitution of cheaper for more expensive agricultural products.[18] The growing popularity of synthetic fibres, rubber and the substitution of vegetable oils for animal fats are examples of this trend. While it is possible to make allowance for such technical changes in a two-product model,[19] it is probably desirable to use a more complicated schema for such a purpose.

The adjustment problem of agriculture could perhaps be examined more realistically with a model which allowed for different rates of technical change in industries supplying farmers' production requisites and in those which purchased farmers' products (e.g. food processing, textiles and marketing firms generally). However this is a more ambitious project which is beyond the scope of this paper.

Another limitation of the above analysis is that technical change has been introduced into the relevant equations as an autonomous variable. It might be more realistic to regard the adoption of technical improvements as an increasing function of price. Such a modification would lessen the likelihood of innovations reducing farm income.

Conclusion

In the analysis of the economic effects of technical change in agriculture, agricultural economists have tended to concentrate on the demand reaction to a relative increase in the output of farm products. I have attempted to show that this is an oversimplified picture of the process of adjustment to technical change. It may be desirable to illustrate the adjustment process to technical change by means of an example.

In 1950 the virus disease myxomatosis was introduced into Australia. This insect borne virus disease initially achieved kills of upwards of 95 per cent of the rabbit population over most of the Australian mainland—

[17] Herbert A. Simon, *op. cit.*, pp. 31-33.
[18] See for instance G. E. Brandow, *op. cit.*
[19] See Herbert A. Simon, *op. cit.*, pp. 38-42 for a similar type of exercise.

at a time when the competition from rabbits provided a major obstacle to increases in wool production and required expensive and laborious countermeasures by farmers, just to keep rabbit numbers stationary.

The virtual elimination of the rabbit from the Australian mainland during the succeeding two seasons increased the quantity of pasture available for sheep (and, to a lesser extent for beef and dairy cattle) and boosted wool output (from the existing sheep population) by an estimated 70 million pounds or six per cent. Apart from this immediate, direct effect, wool production now became much more profitable. Rabbit control expenses disappeared and existing pastures could be used to support a greatly increased sheep population. In addition investment in reseeding pastures with new species and fertilising them became more profitable, as did a host of other investment possibilities such as clearing, fodder conservation, irrigation etc. In terms of our earlier discussion this represents the expansion effect of an innovation—namely an encouragement to switch resources from other avenues of production, or alternatively an incentive to redirect some of the available investible funds to wool production.

While it is not possible to separate the direct and indirect consequences of myxomatosis from other factors (e.g. favourable wool prices in the early fifties, shortages of materials in the previous decade etc.), it seems likely that myxomatosis played an important part—directly and indirectly —in the 50 per cent expansion of Australian wool output during the following decade. (This rate of increase had not been equalled since 1890.)

No doubt partly because of the growth of rival synthetic fibres, but also partly because of the expansion of Australian wool production, relative prices of wool have been declining in recent years. This decline has been represented above as setting in motion the substitution effect. On the demand side (from the Australian point of view) it has stimulated world wool consumption and possibly reduced the rate of growth of output of rival wool suppliers and manufacturers of competitive synthetic fibres. However there is little doubt that the substitution effect is also at work on the supply side. There is evidence that Australian farmers are switching from wool to more reliance on other products such as beef, wheat and dairying and, in some cases, investing surplus funds outside agriculture.

It seems to me that the conventional economic analysis of technical change in agriculture—by concentrating on the demand reactions—has failed to recognise some important aspects of the adjustment process to technical change.

While it has been convenient, in the above example, to treat the expansion and substitution effects as taking place successively in time, this represents an oversimplification which may be justifiable for purposes of

illustration, but may not have any parallel for other innovations or other farm products.

It should also be pointed out that the conclusion reached in Sections I and II of this paper apply only to the situation where technical progress occurs in one sector of the economy and not in the remainder. Where technical progress occurs in "both" sectors but at differential rates, the equations become much more complicated and the conclusions have to be modified. The size of the marginal propensity to consume becomes at least one additional factor determining (a) whether resources will move to, or away from, the sector where innovation has been greater and (b) whether producers in this sector will experience higher or lower gross or net revenues.

But—using the results of the above analysis—it it possible to make some more definite statements about differential technical progress. For differential technical progress can be regarded as a combination of equal technical change in both sectors of the economy and of the situation analysed above (i.e. technical change in one sector only). Where technical change has been greater in sector *A*, it can be shown that resources will move away from *A*-production, given the existence of an inelastic demand with respect to both income and price for product *A*. This proposition can be established rigorously by the use of Simon's proof—referred to above—for the equal technical change situation, and the proof given here for technical change in one sector only.

Appendix

1. *To establish equation (i) in the text* we use the following relations:

$$S_A = g(p, \lambda) = D_A = f(p, y) \tag{1.1}$$

$$S_N = g'(p, \lambda) = D_N = f'(p, y) \tag{1.2}$$

$$y = S_A p + S_N \tag{1.3}$$

where

S_A = supply of product A
D_A = demand for product A
S_N = supply of product N
D_N = demand for product N
y = the community's income
p = the relative price of A (with the price of N taken as unity)
λ = the amount of technical change.

From the theory of production—with full utilization of resources already implied in writing supply as a function of relative price and the technical change parameter λ—it follows that the relative price equals the slope of the transformation curve, i.e.

$$p \frac{\partial S_A}{\partial p} + \frac{\partial S_N}{\partial p} = 0 \tag{1.4}$$

If we define the elasticity of supply of A, i.e.

$$g_A = \frac{\partial S_A}{\partial p}\frac{p}{S_A}$$

it follows from (1.4) that

1.5 $$\frac{\partial S_N}{\partial p} = -g_A S_A$$

or $$\frac{\partial S_N}{\partial p}\cdot\frac{p}{S_N} = -\frac{pS_A}{S_N}\,g_A$$

If we assume that technical change is neutral, i.e., that it raises the marginal products of all factors proportionately at the initial input mix, then it follows that a given percentage change in λ affects the relative cost position of the two industries (and so the supply which each offers) in exactly the same way as an equal percentage increase in p; while in A—where the technical change occurs—output also increases directly (apart from the relative cost change) by the same proportion as λ. In other words:

1.6 $$\frac{\partial S_A}{\partial \lambda}\cdot\frac{\lambda}{S_A} = g_A + 1 \quad \text{or} \quad \frac{\partial S_A}{\partial \lambda} = \frac{S_A}{\lambda}(g_A + 1)$$

and, using 1.5,

1.7 $$\frac{\partial S_N}{\partial \lambda}\,\frac{\lambda}{S_N} = -\frac{pS_A}{S_N}\,g_A, \quad \text{or} \quad \frac{\partial S_N}{\partial \lambda} = -\frac{pS_A}{\lambda}\,g_A$$

The change in the demand for, and supply of, A and N, and in the community's income as a result of technical progress in the production of A can be obtained by differentiating equations 1.1, 1.2 and 1.3 totally, assuming λ changes autonomously.

1.8 $$\frac{dS_A}{d\lambda} = \frac{\partial S_A}{\partial p}\frac{dp}{d\lambda} + \frac{\partial S_A}{\partial \lambda} = \frac{dD_A}{d\lambda} = \frac{\partial D_A}{\partial p}\frac{dp}{d\lambda} + \frac{\partial D_A}{\partial y}\frac{dy}{d\lambda}$$

1.9 $$\frac{dS_N}{d\lambda} = \frac{\partial S_N}{\partial p}\frac{dp}{d\lambda} + \frac{\partial S_N}{\partial \lambda} = \frac{dD_N}{d\lambda} = \frac{\partial D_N}{\partial p}\frac{dp}{d\lambda} + \frac{\partial D_N}{\partial y}\frac{dy}{d\lambda}$$

1.10 $$\frac{dy}{d\lambda} = p\frac{dS_A}{d\lambda} + S_A\frac{dp}{d\lambda} + \frac{dS_N}{d\lambda}$$

Substituting the supply portions of equations 1.8 and 1.9 in 1.10; and using 1.4, 1.6 and 1.7; 1.10 becomes

1.11 $$\frac{dy}{d\lambda} = \frac{pS_A}{\lambda} + S_A\frac{dp}{d\lambda}$$

Substituting 1.11 in equation 1.8 and re-arranging we get:

1.12 $$\frac{dp}{d\lambda}\left[\frac{\partial S_A}{\partial p} - \frac{\partial D_A}{\partial p} - S_A\frac{\partial D_A}{\partial y}\right] = \frac{pS_A}{\lambda}\,\frac{\partial D_A}{\partial y} - \frac{\partial S_A}{\partial \lambda}$$

Substituting 1.6 for $\partial S_A/\partial\lambda$ and solving for $dp/d\lambda$ we obtain, after re-arranging and converting to elasticities:

1.13 $$\frac{dp}{d\lambda} = \frac{p}{\lambda}\,\frac{1 + g_A - C_A}{C_A - E_A - g_A}$$

or $$\frac{dp}{p} = \frac{d\lambda}{\lambda} \frac{1 + g_A - C_A}{C_A - E_A - g_A}$$

where: $$E_A = -\frac{\partial D_A}{\partial p} \frac{p}{D_A} = \text{elasticity of demand for } A$$

$$C_A = p \frac{\partial D_A}{\partial y} = \text{marginal propensity to consume } A$$

To obtain the change in resource use we take equation 1.9 and substitute

$$\frac{\partial S_N}{\partial p} (1.5); \qquad \frac{dp}{d\lambda} (1.13) \text{ and } \frac{\partial S_N}{\partial \lambda} (1.7)$$

After simplifying we get:

1.14 $$\frac{\partial S_N}{\partial \lambda} = -g_A \frac{pS_A}{\lambda} \frac{1 - E_A}{C_A - E_A - g_A}$$

2. *To establish equation (ii) in the text.* The gross revenue (G_A) obtained by producers of A is given by:

2.1 $$G_A = pS_A$$

Differentiating with respect to λ

2.2 $$\frac{dG_A}{d\lambda} = S_A \frac{dp}{d\lambda} + p \frac{dS_A}{d\lambda}$$

Substituting the supply portion of 1.8 and equation 1.6 for $\partial S_A/\partial \lambda$ we get:

2.3 $$\frac{dG_A}{d\lambda} = (g_A + 1) \left[\frac{pS_A}{\lambda} + S_A \frac{dp}{d\lambda} \right]$$

Substituting for $\frac{dp}{d\lambda}$ (1.13) and simplifying we obtain:

2.4 $$\frac{dG_A}{d\lambda} = \frac{pS_A}{\lambda} (g_A + 1) \left[\frac{1 - E_A}{C_A - E_A - g_A} \right]$$

or $$\frac{dG_A}{pS_A} = \frac{dG_A}{G_A} = \frac{d\lambda}{\lambda} (g_A + 1) \left[\frac{1 - E_A}{C_A - E_A - g_A} \right]$$

3. *To establish equation (iii) in the text,* Professor T. W. Swan has suggested the following proof:

Suppose the production functions for A and N are linear and homogeneous; that two factors (x_1 and x_2) are used in their production and of these x_1 is mobile between A and N and x_2 is fixed. The net revenue of producers of A is then identified with the return to those units of x_2 which are employed in the production of A (to be denoted by x_{A2}).

The net revenue accruing to producers of A(i.e. R_A) is given by:

3.1 $$\begin{aligned} R_A &= pS_A - \alpha pS_A \\ &= pS_A(1 - \alpha) \end{aligned}$$

where α is the elasticity of the function with respect to the mobile factor x_1 used in the production of A(i.e. x_{A1}). In terms of the notation used earlier

$$\alpha = \frac{\partial S_A}{\partial x_{A1}} \frac{x_{A1}}{S_A}$$

Differentiating 3.1 logarithmically

3.2 $$\frac{dR_A}{R_A} = \frac{dp}{p} + \frac{dS_A}{S_A} - \frac{\alpha\alpha'}{1-\alpha} \frac{dx_{A1}}{x_{A1}}$$

where $$\alpha' = \frac{\partial(\log \alpha)}{\partial(\log x_{A1})}$$

From the production function for $A = f(x_{A1}\lambda)$ it follows that

3.3 $$\frac{dS_A}{S_A} = \alpha \frac{dx_{A1}}{x_{A1}} + \frac{d\lambda}{\lambda}$$

Substituting in 3.2 and simplifying

3.4 $$\frac{dR_A}{R_A} = \frac{dp}{p} + \frac{d\lambda}{\lambda} + \alpha \frac{dx_{A1}}{x_{A1}} \frac{1-\alpha-\alpha'}{1-\alpha}$$

It can be shown that θ_A–the elasticity of substitution of the production function for A–equals

$$\frac{1-\alpha}{1-\alpha-\alpha'}$$

3.4 then becomes:

3.5 $$\frac{dR_A}{R_A} = \frac{dp}{p} + \frac{d\lambda}{\lambda} + \frac{\alpha}{\theta_A} \frac{dx_{A1}}{x_{A1}}$$

From the equality of returns to each factor in the production of A and N we know that

3.6 $$\alpha p \frac{S_A}{x_{A1}} = \beta \frac{S_N}{x_{N1}}, \quad \text{or} \quad \frac{x_{A1}}{x_{N1}} = \frac{\alpha p S_A}{\beta S_N}$$

Differentiating 3.6 logarithmically

3.7 $$\frac{dp}{p} + \alpha' \frac{dx_{A1}}{x_{A1}} + \frac{dS_A}{S_A} - \frac{dx_{A1}}{x_{A1}} = \beta' \frac{dx_{N1}}{x_{N1}} + \frac{dS_N}{S_N} - \frac{dx_{N1}}{x_{N1}}$$

Substituting for

$$\frac{dS_A}{S_A} \text{ (3.3),}$$

simplifying and using 3.6 we get

3.8 $$\alpha \frac{dx_{A1}}{x_{A1}} = \left(\frac{dp}{p} + \frac{d\lambda}{\lambda}\right) \frac{1}{\frac{1-\alpha}{\alpha\theta_A} + \frac{pS_A}{S_N} \frac{1-\beta}{\beta\theta_N}}$$

It can be shown that the last fraction, i.e.

$$\frac{1}{\frac{1-\alpha}{\alpha\theta_A}+\frac{pS_A}{S_N}\cdot\frac{1-\beta}{\beta\theta_N}}$$

equals g_A—i.e. the elasticity of supply of A.

Substituting in 3.5 and simplifying, the percentage change in net revenue becomes

3.9 $$\frac{dR_A}{R_A}=\left(\frac{dp}{p}+\frac{d\lambda}{\lambda}\right)\left(1+\frac{g_A}{\theta_A}\right)$$

Substituting for dp/p (1.13) and simplifying we get:

3.10 $$\frac{dR_A}{R_A}=\frac{d\lambda}{\lambda}\left(1+\frac{g_A}{\theta_A}\right)\left(\frac{1-E_A}{C_A-E_A-g_A}\right)$$

or $$\frac{dR_A}{d\lambda}=\frac{R_A}{\lambda}\left(1+\frac{g_A}{\theta_A}\right)\left(\frac{1-E_A}{C_A-E_A-g_A}\right)$$

4. *To establish equation (iv) in the text* we use the following relations:

4.1 $$S_{AI}=g(p,\lambda)$$

4.2 $$S_{AO}=h(p)$$

4.3 $$S_{AI}-S_{AO}=D_{AW}=f(p,y_W)$$

4.4 $$S_{NI}=g'(p,\lambda)$$

4.5 $$S_{NO}=h'(p)$$

4.6 $$y_W=S_{AI}p+S_{AO}p+S_{NI}+S_{NO}$$

where the subscripts I and O refer to the innovating country and the rest of the world respectively (and $W=I+O$).

Under these conditions 1.4 can be restated as

4.7 $$p\frac{\partial S_{AI}}{\partial p}+\frac{\partial S_{NI}}{\partial p}=0$$

and $$p\frac{\partial S_{AO}}{\partial p'}+\frac{\partial S_{NO}}{\partial p}=0$$

1.6 and 1.7 can be restated as

4.8 $$\frac{\partial S_{AI}}{\partial\lambda}=\frac{S_{AI}}{\lambda}(g_{AI}+1)$$

4.9 $$\frac{\partial S_{NI}}{\partial\lambda}=-\frac{pS_{AI}}{\lambda}g_{AI}$$

Substituting 4.1 and 4.2 in 4.3 and differentiating 4.3, 4.4, 4.5 and 4.6 totally (with respect to λ), we obtain:

$$4.10 \quad \frac{dS_{AW}}{d\lambda} = \frac{\partial S_{AI}}{\partial p}\frac{dp}{d\lambda} + \frac{\partial S_{AI}}{\partial \lambda} + \frac{\partial S_{AO}}{\partial p}\frac{dp}{d\lambda} = \frac{dD_{AW}}{d\lambda} = \frac{\partial D_{AW}}{\partial p}\frac{dp}{d\lambda} + \frac{\partial D_{AW}}{\partial y_W}\frac{dy_W}{d\lambda}$$

$$4.11 \quad \frac{dS_{NI}}{d\lambda} = \frac{\partial S_{NI}}{\partial p}\frac{dp}{d\lambda} + \frac{\partial S_{NI}}{\partial \lambda}$$

$$4.12 \quad \frac{dS_{NO}}{d\lambda} = \frac{\partial S_{NO}}{\partial p}\frac{dp}{d\lambda}$$

$$4.13 \quad \frac{dy_W}{d\lambda} = p\frac{dS_{AI}}{d\lambda} + S_{AI}\frac{dp}{d\lambda} + p\frac{dS_{AO}}{d\lambda} + S_{AO}\frac{dp}{d\lambda} + \frac{dS_{NI}}{d\lambda} + \frac{dS_{NO}}{d\lambda}$$

Substituting equations 4.11 and 4.12 and the supply portion of equation 4.10 in 4.13 and using 4.7, 4.8 and 4.9 we obtain:

$$4.14 \quad \frac{dy_W}{d\lambda} = S_{AW}\frac{dp}{d\lambda} + \frac{pS_{AI}}{\lambda}$$

Substituting 4.14 in the demand portion of equation 4.10, converting to elasticities by multiplying both sides by p/S_{AW} and re-arranging we obtain:

$$4.15 \quad \frac{dp}{d\lambda} = \frac{S_{AI}}{S_{AW}}\frac{p}{\lambda}\left(\frac{1 + g_{AI} - C_{AW}}{C_{AW} - E_{AW} - g_{AW}}\right)$$

where $g_{AI} = \dfrac{\partial S_{AI}}{\partial p}\dfrac{p}{S_{AI}}$ = elasticity of supply of A from country I

$g_{AW} = \dfrac{\partial S_{AW}}{\partial p}\dfrac{p}{S_{AW}}$ = world elasticity of supply of A

$C_{AW} = p\dfrac{\partial D_{AW}}{\partial y_W}$ = world propensity to consume A

$E_{AW} = -\dfrac{\partial D_{AW}}{\partial p}\dfrac{p}{D_{AW}}$ = world elasticity of demand for A

The gross revenue obtained by producers of A in country I (i.e. G_{AI}) is given by:

$$4.16 \quad G_{AI} = pS_{AI}$$

Differentiating with respect to λ, using the supply portion of equation 4.10, and substituting for $\dfrac{\partial S_{AI}}{\partial \lambda}$ (4.8), we obtain after re-arranging:

$$4.17 \quad \frac{dG_{AI}}{d\lambda} = \frac{dp}{d\lambda}\left(S_{AI} + p\frac{\partial S_{AI}}{\partial p}\right) + \frac{pS_{AI}}{\lambda}(g_{AI} + 1)$$

Substituting for $\dfrac{dp}{d\lambda}$ (4.15), converting $p\dfrac{\partial S_{AI}}{\partial p}$ to g_{AI} and simplifying:

4.18 $$\frac{dG_{AI}}{d\lambda} = \frac{pS_{AI}}{\lambda}(g_{AI} + 1)\left[1 + \frac{\frac{S_{AI}}{S_{AW}}(1 + g_{AI} - C_{AW})}{C_{AW} - E_{AW} - g_{AW}}\right]$$

or $$\frac{dG_{AI}}{G_{AI}} = \frac{d\lambda}{\lambda}(g_{AI} + 1)\left[1 + \frac{\frac{S_{AI}}{S_{AW}}(1 + g_{AI} - C_{AW})}{C_{AW} - E_{AW} - g_{AW}}\right]$$

Using a parallel argument to Section 3 of the Appendix it can be shown that the percentage change in net revenue (R_{AI}) of producers of A in country I is given by

4.19 $$\frac{dR_{AI}}{R_{AI}} = \frac{d\lambda}{\lambda}\left(1 + \frac{g_{AI}}{\theta_{AI}}\right)\left[1 + \frac{\frac{S_{AI}}{S_{AW}}(1 + g_{AI} - C_{AW})}{C_{AW} - E_{AW} - g_{AW}}\right]$$

A MODIFIED SIMPLEX PROCEDURE FOR PROBLEMS WITH DECREASING AVERAGE COST

WILFRED CANDLER AND RICHARD MANNING[1]

THIS article describes a modified simplex procedure for linear programming problems where one or two input coefficients exhibit decreasing average cost, contrary to the usual linear programming assumption of convexity. This problem has received considerable attention lately, and a number of procedures for finding a local optimum have been suggested.[2]

We consider the case where falling average cost[3] occurs with respect to only one or two input coefficients. Parametric programming allows us to examine all points on the relevant section of the production surface and hence to find the plan giving maximum income. Our treatment could be generalized, if it were not for the rapid increase in the computing burden.

A reasonable basic knowledge of linear programming is assumed, together with the computing procedure for "variable input coefficient" programming.[4] It is also assumed that the reader knows of the "convexity assumption," and the difficulty associated with increasing marginal products.[5]

We will first provide a graphical solution of a very simple problem. This problem will then be analysed numerically, and finally a more realistic problem will be analysed.

A Two-Dimensional Problem

Suppose we were faced with the following linear programming problem:

Maximize

$$Z = x_1 + x_2$$

[1] Massey Agricultural College (University of New Zealand), Palmerston North, N.Z., and the University of New England, Armidale, N.S.W., Australia.

[2] Harald Giaever and James Seagraves, "Linear Programming and Economies of Size," *J. Farm Econ.*, 42:103-17, Feb. 1960. Harry M. Markowitz and Alan S. Manne, "On the Solution of Discrete Programming Problems," *Econometrica*, 25:84-110, Jan. 1957. Ralph E. Gomory, "Essentials of an Algorithm for Integer Solutions to Linear Programs," *Bul. of Am. Math. Soc.*, 64:275, 1958. The first example in this article is taken from Method B of the Giaever-Seagraves article.

[3] Elsewhere called "increasing marginal product" or "economies of size," see Giaever and Seagraves, *op. cit.*, and Markowitz and Manne, *op. cit.*

[4] Earl O. Heady and Wilfred Candler, *Linear Programming Methods*, Ames, Iowa: Iowa State Univ. Press, 1958, Chap. 16. A concise account of our computing procedures is included in an appendix to this article.

[5] Giaever and Seagraves, *op. cit.*, pp. 103-04; Heady and Candler, *op. cit.*, pp. 220-26; Robert Dorfman, Paul A. Samuelson and Robert M. Solow, *Linear Programming and Economic Analysis*, New York: McGraw-Hill, 1958, pp. 396-99.

subject to

$$\begin{aligned} .15x_1 + tx_2 &\leq 1 \\ .25x_1 + .1x_2 &\leq 1 \end{aligned} \tag{1}$$

and

$$x_1, x_2 \geq 0$$

where

$$t \geq .25 - .01x_2 \tag{2}$$

t is, of course, the per unit average requirement of the first resource by the second activity when x_2 is at a given level. The total requirement, T, of the first resource for a given level of x_2 may be written:

$$T = tx_2 \geq .25x_2 - .01x_2^2 \tag{3}$$

An inequality is used since we can always allow some of the resource to be used inefficiently.

As a first step to the solution of this problem we might reasonably graph (2) as in Figure 1, to give the general relationship between the average input requirement t, and the level of the second activity, x_2. The horizontally shaded area is infeasible since it violates the inequality (2).

Clearly, the appropriate value of t to use in (1) is a function of the level of x_2, and the fact that it would not pay to produce at one level of x_2 is no guarantee that a *higher* level of x_2 (and hence a lower value of t) would not be profitable.

The next graphical (and algebraic) step might be to calculate (parametrically) the optimum plan for all values of t, from .25 to 0. The derivation of these optimum plans is detailed in the appendix, and the optimum plans are given in Figure 2.

As would be expected, examination of Figure 2 reveals that as t decreases, there is a tendency for the production of P_2 to increase. Income

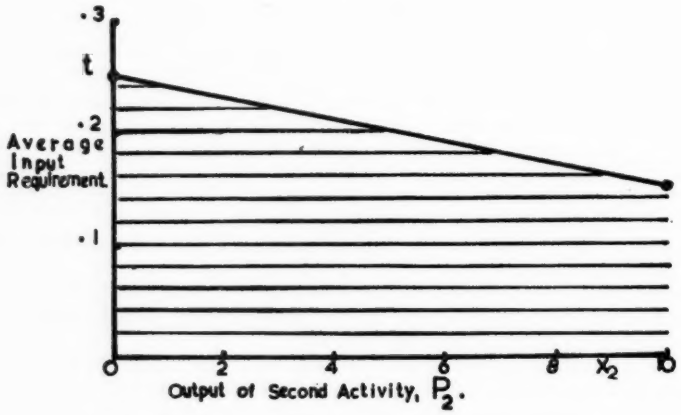

FIG. 1. FALLING AVERAGE RESOURCE REQUIREMENT.

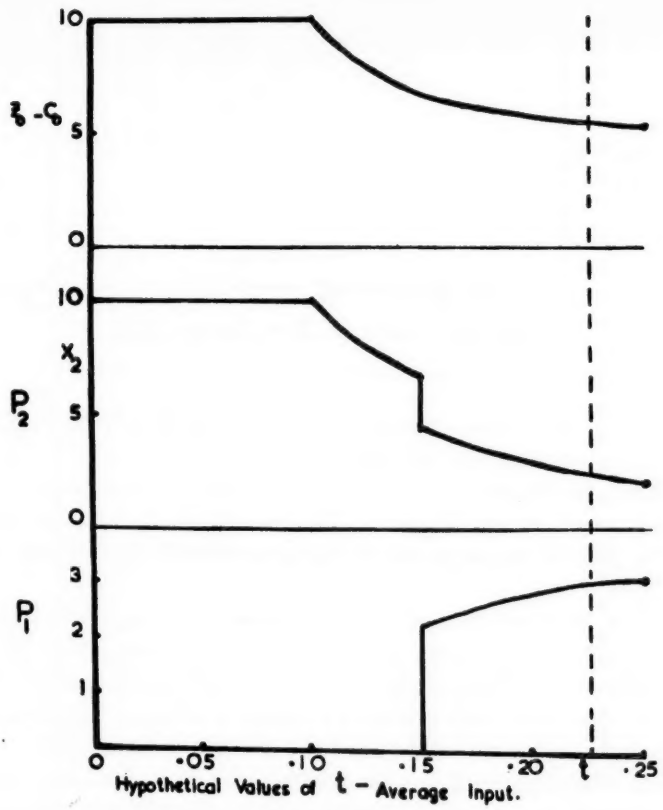

FIG. 2. OPTIMUM PLANS AS A FUNCTION OF T.

increases monotonically as t decreases. The smaller the value of t, all other things being equal, the higher the income. The P_2 line gives the optimum (income maximizing) quantity of P_2 corresponding to each value of t. Obviously, if we were willing to accept a lower income, we could provide a variety of plans (for given t), which would include either more or less P_2, than in Figure 2. *There would, however, be a maximum amount of P_2 which could be produced for each value of t.* In particular, in (1), if $t = .25$ we could not produce more than 4 units of P_2 ($x_2 = 4$). The maximum quantities of P_2 consistent with each value of t have been graphed in Figure 3.[6] The quantities of P_2 needed to maximize income have been inserted as a broken line. Clearly, for any given value of t, as we move from the broken to the unbroken line (a vertical movement upwards in Figure 3), income will decrease monotonically. The vertically shaded area above the unbroken line is infeasible in the sense that it cannot be achieved without violating one or more of the inequalities in

[6] The derivation of this figure is discussed in the appendix.

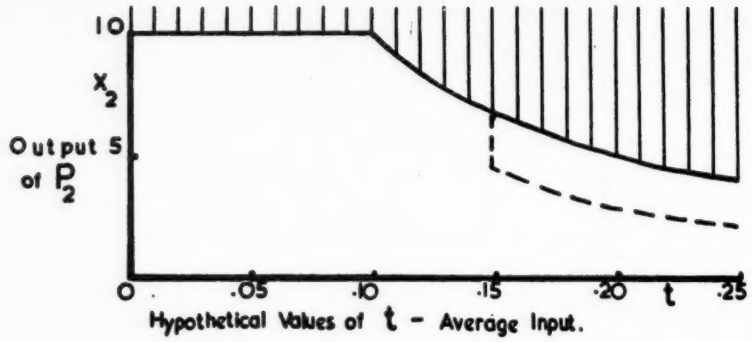

FIG. 3. MAXIMUM PRODUCTION OF P_2 AS A FUNCTION OF T.

(1). Similarly, as we move to the left along the broken line, we know, from Figure 2, that income will increase.

Returning to Figure 1, we can see that it has the same axes as Figure 3 (turned through ninety degrees). The area below the line in Figure 1 is infeasible since it corresponds to the area which violates the inequality (2).

In Figure 4, Figures 1 and 3 have been superimposed. The vertical shading delineates the area which violates the inequalities (1) and the horizontally shaded area violates the technical restriction (2). Thus, the unshaded area is the only portion of Figure 4 which is consistent with (1) and (2), and may be referred to as the *mutually feasible area.*

In discussing Figure 2 we established that as t decreases the income associated with the optimum plan increases monotonically. Thus in Figure 4 the income at B is as high as or higher than the income at A.

In discussing Figure 3 we pointed out that for given t, income decreases monotonically as the level of an activity is increased above the level dictated by the optimum plan. Thus (given the level of t) the plans corresponding to the border $B\beta$ in Figure 4 have higher incomes than any

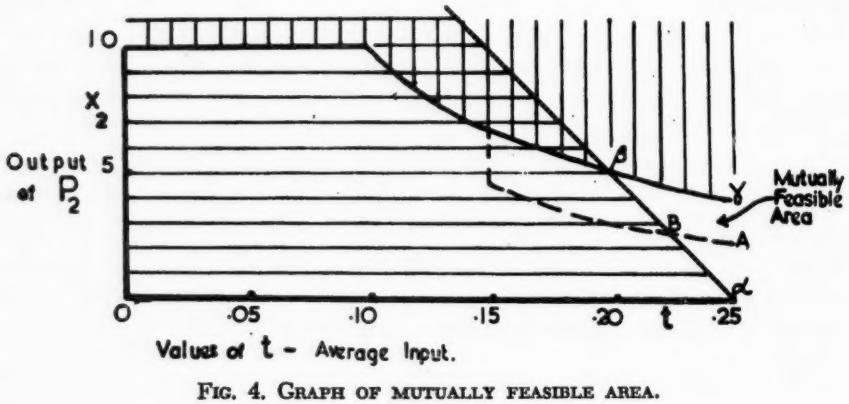

FIG. 4. GRAPH OF MUTUALLY FEASIBLE AREA.

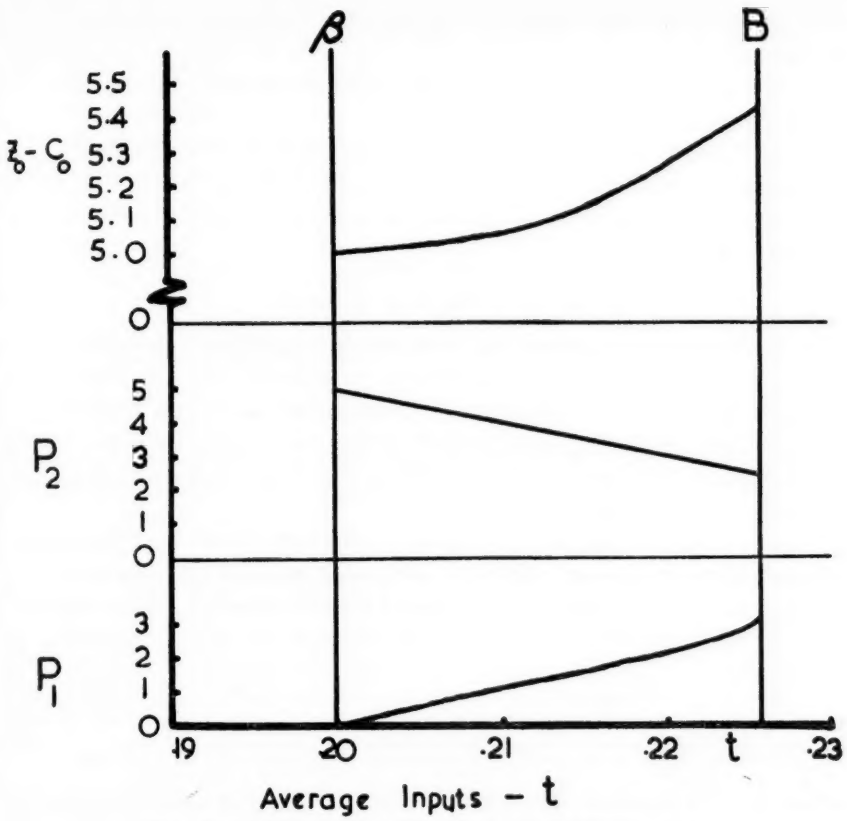

FIG. 5. PLANS ON THE MUTUALLY FEASIBLE BORDER β.

other plans in the mutually feasible area. Thus, if we examine all plans on the border $B\beta$, including the income maximizing plan B, we will have found the *maximum maximorum*. The plans corresponding to the border $B\beta$ are graphed in Figure 5. The computational details are included in the appendix.

Quite obviously, the optimum plan, given an increasing marginal product for some resource, will be found if we examine all points on the appropriate border of the mutually feasible area.

It is clear from an inspection of Figure 5 that the most profitable point on the mutually feasible border $B\beta$ occurs at B. It is equally clear that with a slightly more rapidly increasing marginal product, β could easily be the most profitable point.

Summary

Our procedure may be summarised:

1. State the problem as a parametric programming problem, where the value of the input coefficient t is to be varied.

2. Assign t a value large enough that the technical restriction is inoperative.

3. Allow t to decrease in magnitude until the technical restriction becomes operative.

4. *Examine the whole surface* which is consistent both with the technical restriction and the other restrictions on the matrix.

5. The maximum income obtained as a result of step 4 indicates the optimum plan.

A More Realistic Example

It has been shown above that parametric programming enables us to obtain the optimum plan, the *maximum maximorum*, for a problem with two activities and two resource restrictions, when one input coefficient is characterized by falling average cost. When all is said and done, this is no very great achievement—we could find the optimum plan by graphical methods or budgeting.

This section discusses a rather more realistic problem, with five activities and three resources.[7] There is a dairying activity and two crop and two hog feeding activities. It is assumed that the average labour requirement for dairying, P_5, is a function of the level of output, according to the relation:

$$d \geq 1 + \frac{3}{x_5} \tag{4}$$

where d is the per unit labour requirement of dairying and x_5 is the number of cows being milked, i.e., the level of P_5).

The capital requirements of the cropping and dairying enterprises depend on the cost of machinery, as follows:

$$\begin{aligned} &\text{For Corn } A\ (P_1): && c_1 \geq 10 + 20m \\ &\text{For Corn } B\ (P_2): && c_2 \geq 24.5 + 30m \\ &\text{For Dairying } (P_5): && c_5 \geq 12 + 5m \end{aligned} \tag{5}$$

where m is the per unit cost of machinery; i.e. the three activities have capital requirements of 10, 24.5 and 12 respectively which are not connected with the use of machinery. The three activities use machinery in the ratio 20:30:5, and hence we can write the total machine hours as:

$$M = 20x_1 + 30x_2 + 5x_5 \tag{6}$$

Further, we assume that machine services may be obtained either from a contractor or from a small or a large machine. The cost for the small or the large machine depends, of course, on the total number of hours, M,

[7] Based, in part, on Heady and Candler, *op. cit.*, p. 272.

for which it is used. The three alternative sources of machine services have cost functions:

$$\begin{aligned} &\text{Contractor:} && m_1 = 2 \\ &\text{Small machine:} && m_2 = .5 + \frac{75}{M} \\ &\text{Large machine:} && m_3 = \frac{150}{M - 150}, \quad M > 150 \end{aligned} \tag{7}$$

It is a simple matter to check that the cost of machine services will be minimised by the decision rule:

$$\begin{aligned} &\text{Use contractor if} && M < 50 \\ &\text{Use small machine if} && 50 < M < 362 \\ &\text{Use large machine if} && 362 < M \end{aligned} \tag{8}$$

The above cost functions have been graphed in Figure 6.[8]

The other input coefficients for this problem appear as in Table 1, the values of c_1, c_2, c_5 and d being given by equations (4) and (5).

TABLE 1. INPUT COEFFICIENTS FOR "MORE REALISTIC" EXAMPLE

Resource	Supply	Activities				
	B	Corn A P_1	Corn B P_2	Hogs A P_3	Hogs B P_4	Dairy P_5
Capital	500	c_1	c_2	100	105	c_5
Labour	20	1	2	2	1.5	d
Grain	0	−1	−2.1	1	2.5	1
Revenue	0	2	2.2	28	40	28

If we start with large values of d and m (high initial input coefficients) we can be fairly sure that the inequalities (4) and (5) will be satisfied. From (7) we know that the largest value of m is 2, and $d = 10$ seems a reasonably large initial average labour input for dairying. Use of $m = 2$ implies $c_1 = 50$, $c_2 = 84.5$, and $c_5 = 22$. Thus the first simplex tableau becomes that shown in Table 2. Here X_d and X_m are related to d and m by the relations:

$$d = 10\left(1 - \frac{1}{X_d}\right), \qquad m = 2\left(1 - \frac{2}{X_m}\right) \tag{9}$$

[8] Similar cost functions for the application of nitrogenous fertilizer appear in Heady, Earl O., and Baum, E. L., "Economic Comparison of Farm Applications of Dry and Liquid Types of Nitrogen in Iowa," in *Fertilizer Innovation and Resource Use*, edited by Baum, E. L., *et al*, Iowa State Univ. Press, Ames, 1957, p. 89.

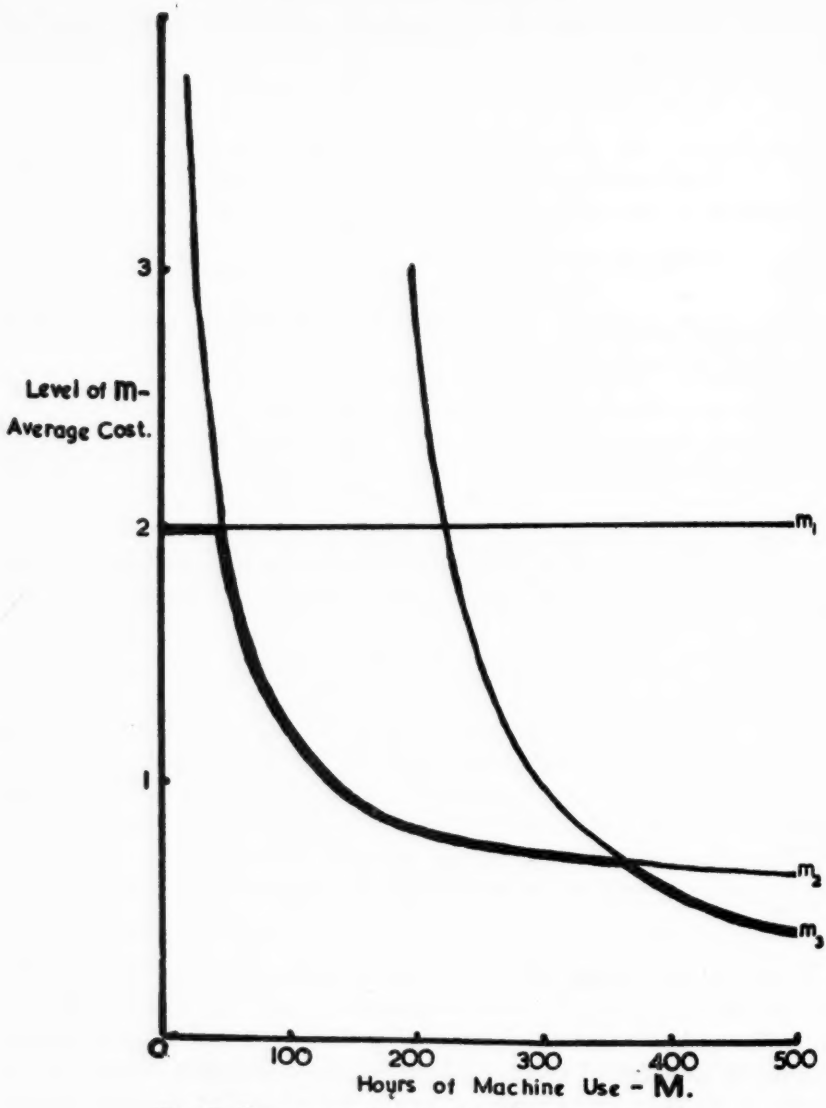

FIG. 6. COST OF FUNCTIONS FOR MACHINE SERVICES.

Setting X_d and X_m equal to plus infinity (so that $d = 10$, $m = 2$) and solving the problem in Table 2 gives Plan a of Table 3. This plan is consistent with (4) and (5), and is optimum for $d = 10$, $m = 2$.[9]

[9] For this "more realistic" example the authors have confined themselves to quoting results. The full details of the computations are available on request. See: Candler, Wilfred, *An Example of Linear Programming Where Two Input Coefficients Exhibit Falling Average Cost*, Computing Tract No. 1, Faculty of Agricultural Economics, Univ. of New England, Armidale, N.S.W., Australia.

TABLE 2. INITIAL SIMPLEX COMPUTING TABLEAU

Resource	Supply B	Real Activities					Efficiency Activities	
		Corn A P_1	Corn B P_2	Hogs A P_3	Hogs B P_4	Dairy P_5	Labour P_7	Machinery P_7
Capital P_8	500	50	84.5	100	105	22	0	−1
Labour P_9	20	1	2	2	1.5	10	−1	0
Grain P_{10}	0	−1	−2.1	1	2.5	1	0	0
Labour P_{11}	0	0	0	0	0	−10	X_d	0
Machinery P_{12}	0	−20	−30	0	0	− 5	0	X_m
$Z_j - C_j$	0	− 2	− 2.2	−28	−40	−28	0	0

Note: To save space the unit matrix of disposal activities has been omitted.

Since neither of the inequalities (4) or (5) are effective (in the sense of influencing the choice of plan), we could derive another plan for smaller values of d and m; and since the lower the average cost the higher the profit is likely to be, we would expect a decrease in d and m to increase profit.

If we allow d to decline parametrically, while holding m constant at 2, we get, successively, Plans b, c and d of Table 3. With Plan d ($d = 1.54$, $m = 2$) it is impossible to increase income further unless m is allowed to decrease. In fact, Plan d corresponds to the point at which labour becomes a free resource; a further decline in the average labour requirement for dairying only results in additional labour being allocated to disposal. Plan d′ ($d = 1.37$) corresponds to minimum average labour requirement for dairying (given $m = 2$, and inequality (4)). We italicise *8.03* in the d′ row to indicate that the inequality (4) is in part responsible for the value. (This is in contrast to the first four entries in the P_5 column which just

TABLE 3. SUMMARY OF PLANS

Plan Index	Input Coefficients		$Z_0 - C_0$	Plan				
	d	m		P_1	P_2	P_4	P_5	M
a	10	2	121.09		3.02	2.10	1.08	96.01
b	2.28	2	186.43		3.49	.88	5.13	130.30
c	1.88	2	208.35	6.94			6.95	173.61
d	1.54	2	233.37		3.83		8.03	154.94
d′	1.37	2	233.37		3.83		*8.03**	154.94
e	1.34	1.50	253.02		4.15		*8.71**	168.05
f	1.35	.94	255.04	8.50			*8.50*	212.56
f′	1.35	.85	255.04	8.50			*8.50**	*212.56**
g	1.34	.95	253.02		4.15		*8.71**	*168.05**
h	1.38	.88	251.22	9.16		.32	*7.85**	*222.44**
i	$+\infty$	.79	153.24	12.77		3.19	0*	*264.42**

happen to correspond to critical, border, plans in the parametric solution.) The asterisk indicates that *even if we were willing to withdraw resources from more profitable employment,* we could not increase the amount of P_5 in the plan (unless, of course, we managed to reduce m).

From Plan d we can move to Plans e and f by lowering m parametrically. We can do this while always keeping d at *its most profitable level for the given value of* m—that is, the movement from Plan d to e to f corresponds to sidling along restriction (4) while allowing m to fall. Our parametric solution says that at Plan f there is no way of increasing income further. That is, a further reduction in m will not increase income. In this case capital has become a free resource, and a further decline in average cost will only lead to additional amounts of capital being allocated to disposal. We can, however, move to Plan f′ (m reduced from .94 to .85) without loss of income. The parametric solution suggests that Plan f (or f′) probably gives maximum income. To put this another way: unless the reduction in average cost is so marked that it pays to withdraw resources from other enterprises (just to achieve the lower average cost) Plan f (or f′) is optimum.

The locations of the plans in Table 3 have been graphed (in terms of their d and m co-ordinates) in Figure 7. The heavy line indicates the course of the normal parametric solution. Looking at Figure 7, we can see that a move from north-east to south-west cannot decrease income. Unless both capital *and* labour have become free resources it will increase income. A move from north-west to south-east may *increase or decrease* income. Thus on the assumption that either labour or capital has some value *the move from* d *to* e *must increase income.* The move from e to f may or may not. In fact, the move from e to f does increase income (from 253.02 to 255.04).

Looking at Plan f′ we see that both the P_5 and M entries are starred. This means:

1. Given $m = .85$, we cannot reduce d below 1.35, and
2. Given $d = 1.35$, we cannot reduce m below .85.

These two statements together mean that *we cannot move "south-west" from Plan* f′, *even if we were willing to use our total resource supply on dairying and machine usage.* This in turn means that we can only move south-east or north-west from Plan f′ with any possibility of increasing income.

Now taking the above discussion and the restrictions imposed by Table 1 and (4) and (5), we see that there must be a functional relation between d and m:

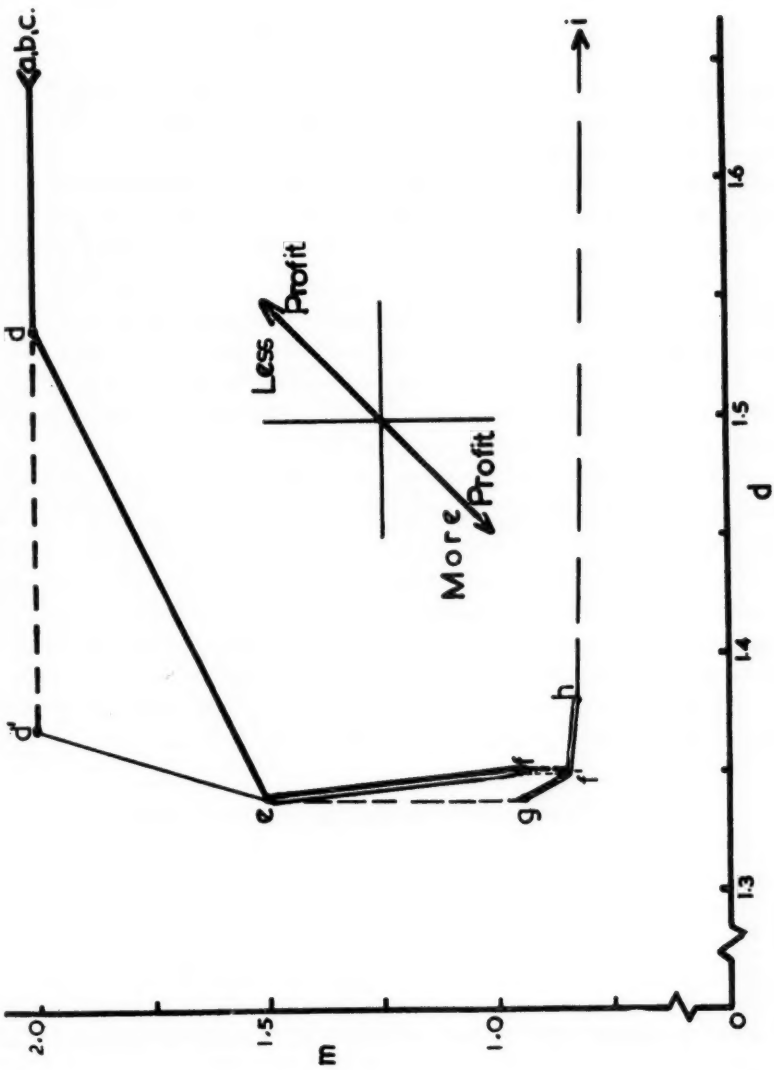

FIGURE 7.

$$m^* = f(d^*) \tag{10}$$

such that:

1. Given $d = d^*$ it is impossible to reduce m below m^*, and
2. Given $m = m^*$ it is impossible to reduce d below d^*.

In short the function (10) *gives all those combinations of d and m from which we cannot move south-west even if we were willing to use all our resources in the attempt.*[10]

The appropriate computing routine[11] results in our moving from Plan e to g, to f', to h, to i. In Table 3, Plans g, f', h and i have stars in both the P_5 and M columns, indicating that from each of these plans we cannot move south-west. Thus these plans trace out the function (10). Since points south-west of gf'hi are *infeasible,* the maximum profit plan must be on this line or north-east of it. Also, as we move north-east or east of the heavy line income decreases. Bearing these two facts in mind, and inspecting the Z_0-C_0 column of Table 3, it is fairly clear that the maximum income is given by Plan f or f'.

It might be thought that the plans intermediate between g and f' and between f' and h should be inspected, since there might be a still higher income plan "close to f'." Obviously, from the general regularity of the surface *in this case,* there is not going to be a maximum anywhere other than near f. In a more complicated example, we might have to "inspect" several regions of the income surface. A range of plans on the border gf'h are given in Table 4. This table completes the solution.

The optimum plan consists of 8.5 units of Corn A and 8.5 units of dairying—and the farmer should buy the small machine.

TABLE 4. PLANS INTERMEDIATE BETWEEN PLANS g, f' AND h

d	P_1	P_2	P_5	Z_0-C_0	Remarks
1.344	0	4.15	8.71	253.01	Plan g
1.346	2	3.17	8.66	253.45	
1.348	4	2.20	8.61	253.92	
1.350	6	1.22	8.56	254.36	
1.352	8	.25	8.51	254.83	
1.353	8.5	0	8.50	255.00	Plan f'
1.358	8.63	0	8.38	251.90	
1.363	8.75	0	8.25	248.50	
1.369	8.88	0	8.13	245.40	
1.375	9.00	0	8.00	242.00	Integer sol.
1.383	9.17	0	7.84	237.86	Plan h

[10] "The attempt" would consist of allocating all our resources to dairying and machine services.

[11] Candler, W., *op. cit.*

APPENDIX

Since some readers may not have an account of variable input programming available, or may have difficulty in applying it to this particular problem, the computations for the simple problem are given in this appendix.

In Table 1a, activities P_1, P_2, P_3 and P_4 come from the original statement of the problem (except that t has been set equal to .25, the largest value of interest).[1]

Activities P_5 and P_6 have been added to allow us to estimate the effect of a change in the value of t. Row P_5 indicates the quantity of resource P_3 being used by activity P_2. Hence, for any given change in the magnitude of t, P_5 *records the units of* P_3 *which would be affected.* Thus in the third iteration .526 units of P_3 are being used by activity P_2, and hence a 10 percent increase in the efficiency of conversion would release, in the first instance, .0526 units of P_3 for reallocation.

TABLE 1a. CALCULATION OF SIMPLE EXAMPLE

	B	P_3	P_4	P_5	P_1	P_2	P_6	
P_3	1	1	0	0	.15	.25	−1	
P_4	1	0	1	0	.25	.1	0	
P_5	0	0	0	1	0	− .25	X	
$Z_j - C_j$	0	0	0	0	−1	−1	0	
P_3	.4	1	− .6	0	0	.19	−1	
P_1	4	0	4	0	1	.4	0	
P_5	0	0	0	1	0	− .25	X	
$Z_j - C_j$	4	0	4.0	0	0	− .6	0	P_6'
P_2	2.105	5.263	−3.158	0	0	1	−5.263	−5.263
P_1	3.158	−2.105	5.263	0	1	0	2.105	2.105
P_5	.526	1.316	− .790	1	0	0	X−1.316	9.051
$Z_j - C_j$	5.263	3.158	2.105	0	0	0	−3.158	−3.158
P_2	2.410							
P_1	3.036							
P_6'	.058							
$Z_j - C_j$	5.446							

Column P_6 allows the supply of P_3 to be increased. *The size of the increase will be affected by the magnitude of* X. If X is "plus infinity," P_6 will come in, at zero level, against the P_5 restriction, and the corresponding plan will be unaffected. Thus an X value of plus infinity corresponds to "no decrease in t," and *if* t is .25, then the third iteration gives the optimum plan. Thus *the effective value of* t, t', in the computing tableau depends not only on the value

[1] The increasing marginal product relationship is given by

$$t \geqslant .25 - .01\ x_2 \qquad (2)$$

Thus even if x_2 is zero, t cannot be larger than .25.

at the intersection of the P_3 row and P_2 column, .25, but *also on the value assigned to X*. For every unit of P_3 used by P_2, $1/X$ units are "returned" via P_6. Hence the effective value of t is reduced in the ratio $1 - (1/X)$, so that t' is:

$$t' = .25\left(1 - \frac{1}{X}\right) \tag{1a}$$

In particular, when $X = \infty$, $t' = .25$, and when $X = 1$, $t' = 0$, i.e. all P_3 used by P_2 is "returned." It is not really necessary to formally include P_5 and P_6 in the matrix, since P_6 is merely the negative of P_3 disposal (with the addition of X) and once P_2 has come into the plan, P_5 is .25 (the appropriate input coefficient) times the corresponding level of entry of P_2.

As X is reduced, t' is reduced as in (1a). If we wished to examine the effect of a 1 percent decrease in t, we would set $1 - (1/X) = .99$ or $X = 100$. The coefficient at the intersection of the P_5 row, P_6 column would be 98.684, and the optimum plan would be:

$$\begin{aligned} P_2 &= 2.133 \\ P_1 &= 3.147 \\ P_6 &= .0053 \\ Z_j - C_j &= 5.280 \end{aligned}$$

The interested reader can check that this *is* the optimum plan by setting $t' = .25 \times .99 = .2475$ in the first tableau and omitting P_5 and P_6.

Inspection of the third section of the tableau reveals that as X decreases (and t' decreases) income and the production of P_2 will increase while the production of P_1 will decrease. There are, however, limits beyond which the optimum adjustment will be different. Thus, once the supply of P_2 has been reduced to zero, further decreases in t' will have a different impact. Similarly, there may come a time when some other activity should be brought into the plan, or when the restriction (2) may be violated. Each of these possibilities defines a critical value of X, which is designated X_c, X_r, or X_t for a column, a row, or a technological restriction.

The technological restriction

In the third section of the tableau (with $X = \infty$) we have $t' = .25$ and $x_2 = 2.105$; hence the technological inequality (2) is satisfied. We have seen that as X decreases so will t, and x_2 will increase. It is unlikely, however, that the rise in X_2 will be sufficiently fast to ensure that (2) continues to hold.

The value of X, X_t, at which (2) becomes an equality can be calculated from the solution of the set of equations:

$$\begin{aligned} t' &= .25 - .01x_2 \\ t' &= .25\left(1 - \frac{1}{X}\right) \\ x_2 &= 2.105 - \left(\frac{.526}{X - 1.316}\right)(-5.263) \end{aligned} \tag{2a}$$

where (2a) is obtained from the third section of the computing tableau, and x_2 is the value in the P_2 column when P_6 has been introduced against P_5 according to the normal simplex rules. The critical values turn out to be:

$$X_t = 10.367,\ x = 2.41,\ t' = .226$$

The column restriction

We now need to check that row or column restrictions do not change the plan for values of X in excess of 10.367.

The column restriction is that the introduction of P_6 must continue to be limited by P_5. This corresponds to:

$$R_5 \leq \min_i R_i$$

where R is the usual simplex ratio. In particular

$$\frac{.526}{X_c - 1.316} \leq \frac{3.158}{2.105}$$

or

$$X_c \geq 1.662$$

The row restriction

The row restriction is that when P_6 is introduced the other $(Z_j - C_j)$'s should remain positive. Formally, if $(Z_j - C_j)'$ is the $(Z_j - C_j)$ value after introduction of P_6, we have the restriction:

$$(Z_j - C_j)' = (Z_j - C_j) - \frac{(a_{5j})(-3.158)}{X - 1.316} \geq 0$$

Since $(Z_j - C_j)$ is positive initially, this will always hold unless $a_{5_j} < 0$. Hence the restriction becomes:

$$\left\| \frac{a_{5j}}{Z_j - C_j} \right\| \leq \frac{X - 1.316}{3.158}, \qquad a_{5j} \overset{\text{as}}{<} 0$$

Writing

$$S_j = \left\| \frac{a_{5j}}{Z_j - C_j} \right\|$$

we have the condition

$$X \geq 1.316 + 3.158 \min_j S_j$$

In particular

$$X_r \geq 1.316 + 3.158 \left\| \frac{-.790}{2.105} \right\|$$

$$X_r = 2.5$$

Having calculated the critical ratios, we now select max (X_c, X_r, X_t), which in this example is X_t. For this value of X and the corresponding value of t' the technological restriction becomes effective.[2] We substitute this value to get P_6', and use P_6' to get the next section of the tableau. The interested reader may check that the new entries give the optimum plan corresponding to $t' = .226$ in the first section.

It is a simple matter to obtain plans corresponding to the border $B\beta$, i.e. for values of t' $(t' < .226)$ where the technological restriction holds. Solving (1a) for X, we have:

$$X = \frac{1}{1 - 4t'} \tag{3a}$$

[2] If X_r or X_c had become effective rather than X_t, we would have made the appropriate adjustments (Heady and Candler, *op. cit.*) and continued to allow t' to fall (with a corresponding increase in income) until X_t became effective.

TABLE 2a. NON-FEASIBLE PLANS FOR SMALL VALUES OF t'

t':	.226	.22	.21	.20	.19
P_2	2.410	2.5	2.668	2.858	3.2
P_1	3.036	3	2.933	2.857	2.72
P_6	.058	.075	.107	.143	.208
$Z_j - C_j$	5.446	5.5	5.601	5.715	5.92
$X_{2\,\min}$	2.410	3	4	5	6
$X_2 - X_{2\,\min}$	0	− .5	−1.332	−2.142	−2.8

Hence we have:

t'	X	*Pivot,* $X - 1.316$
.22	8.333	7.017
.21	6.250	4.934
.20	5.000	3.684
.19	3.846	2.530

Using these pivots in place of 9.051 in the third section of Table 1a, we obtain the plans listed in Table 2a.

The $x_{2\,\min}$ row gives the level of x_2 necessary to justify the corresponding value of t'. Thus the $x_{2\,\min}$ row is derived from (2). Clearly only the first plan of Table 2a is feasible. All the rest violate (2). All but the last of these plans can, however, be made feasible by expanding the production of P_2. This expansion of P_2 can only be achieved by bringing P_4 into the plan (since it is the only activity with a negative in the P_2 row).[3] The P_3 columns and optimum feasible plans for the t' values given in Table 2a are shown in Table 3a.

The P_3 columns of Table 3a are calculated in the usual way from the third section of Table 1a, using the pivots previously calculated. The quantity of P_3 to be brought into the plan is dictated by the deficiency in x_2 production (indicated by the last row of Table 2a) and the quantity of P_2 produced per unit

[3] More generally, we would introduce the activity which could increase the output of P_2 *at minimum cost.*

TABLE 3a. OPTIMUM PLANS FOR SMALL VALUES OF t'

t':	.22		.21		.20		.19	
	P_3	Plan	P_3	Plan	P_3	Plan	P_3	Plan
P_2	−3.753	3	−4	4	−4.284	5	−4.8	6
P_1	5.501	2.268	5.6	1.068	5.713	0	5.92	− .731
P_6	− .113	.09	− .160	.160	− .214	.250	− .312	.390
P_3	1	.133	1	.333	1	.500	1	.583
$Z_j - C_j$	1.748	5.268	1.6	5.068	1.429	5.000	1.12	5.267
$X_{2\,\min}$		3		4		5		6

of P_3 (given by the first row of Table 3a). For example, for the ($t' = .22$) plan we have

$$P_3 = \frac{.5}{3.753} = .133$$

The right hand plan of Table 3a has a negative supply of P_1. This indicates that the plan is infeasible. Further examination of the whole matrix would indicate that there is no other way of increasing the supply of P_1 or P_2. This in turn indicates that the plan for $t' = .2$ represents the maximum production of P_2 consistent with (1) and (2). The plan for $t' = .2$ corresponds to β in Figure 4.

A GENERAL ANALYTICAL FRAMEWORK FOR ESTIMATING THE PRODUCTION FUNCTION FOR CROPS USING IRRIGATION WATER*

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THE primary objective of this paper is to develop an analytic methodology which can serve as a basis to estimate the production function for crops using irrigation water. Within this methodology we will attempt to show how it is possible to impute a value to the irrigation water applied within any one irrigation cycle.

A further objective is to develop a model to determine an optimum irrigation program which could bring into account varying water prices and changing commodity prices during the growing season.

Plant-Soil Moisture Relationship[2]

A review of the literature on the relationship of soil moisture to plant growth discloses several schools of thought. The oldest school—sometimes called the "more water, more plant school," holds that the growth rate progressively diminishes as the available soil moisture content falls below the field capacity (F.C.)[3] of the soil, and ceases when the permanent wilting point (P.W.P.)[4] is reached. This concept, although underlying many early irrigation field trials, has little current support.[5] A second school, led by Veihmeyer and Hendrickson,[6] holds the retardation of plant

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[1] The author would like to acknowledge with appreciation help given by Dr. Yoash Vaadia, Department of Irrigation, University of California, and by his colleague, Dr. T. R. Hedges.

[2] An extensive review of agronomic literature on this subject from the standpoint of economic implications is presented in Christoph Beringer, "Some Conceptual Problems in Determining the Production Function for Water," *The West in a Growing Economy* (Proc. of the Western Farm Econ. Assoc., 32nd ann. meeting, July 14-17, 1959) pp. 58-70; and *idem, An Economic Model for Determining the Production Function for Water in Agriculture,* Calif. Agr. Expt. Sta., Giannini Found. Res. Rept. No. 240, Feb. 1961.

[3] The amount of water retained in a deep well-drained soil after it has been wetted and drainage has taken place. Booher, L. J., and C. E. Huston, *Water Holding Characteristics of Some California Soils,* Univ. of Calif., Mimeo. (Berkeley: 1958), p. 1.

[4] Percent moisture remaining in the soil when plants wilt and fail to recover turgidity when placed in a high humidity chamber. Booher and Huston, *op. cit.,* p. 1.

[5] Hagen, Robert M., "Factors Affecting Soil Moisture–Plant Growth Relations," *Report of the XIV International Horticultural Congress,* Scheveningen, Netherlands, 1955, p. 86.

[6] Hendrickson, A. H., and F. J. Veihmeyer, *Irrigation Experiments with Grapes,*

growth is negligible until the soil is very near the permanent wilting point. This is sometimes referred to as the "equal availability theory."

The foremost school of thought[7] the body of theory that has the majority of the literature defending it—holds that in general the relative rate of plant growth is a function of the mean soil moisture stress in the active root zone; that is, plant growth is related to the tension with which the moisture is held to the soil particles. This stress varies directly with (a) the number of soil particles in a given volume, (b) the osmotic effect of salts present in the soil, and (c) the level of depletion of the available soil moisture. For a nonsaline sandy soil, until the depletion of soil moisture approaches the permanent wilting point, there will be very little retardation of plant growth.[8]

Most irrigationists recognize today that the relationship is not a fixed one, but may vary under different conditions. Therefore, it is difficult to express the relationship precisely in a generalized mathematical form.[9]

Some plant scientists who support the moisture stress concept concede that these curves do not reflect the precise plant-soil water relationship. They suspect that brief periods of high moisture stress can have an exaggerated effect on plant growth. (Such an effect has been pointed out in irrigation studies on field corn by Rhoades and Nelson.)[10] Proponents of the average moisture stress school recognize this variation, and agree that their curves may not adequately express the physiological effect of extreme variations in moisture stress over the irrigation cycle. Nonetheless, they hold that their curves provide the best approximation available for the widest range of crops, soil and climatic conditions until more definitive evidence is discovered.

For the purpose of this paper, it is assumed that there is a definite relationship between plant growth and the mean moisture stress values which are present in the soil. This is necessarily an approximation but nevertheless one which would represent most of the situations encountered in the field.[11]

This latter assumption indicates that the shape of the moisture stress curves will change with the soil type and the amount of salt present, as

Univ. of Calif. Agr. Exp. Sta. Bul. 728 (Berkeley: 1950); also, Veihmeyer, F. J., and A. H. Hendrickson, "The Effects of Soil Moisture on Deciduous Fruit Trees," *International Horticultural Congress*, 1952, vol. 1, pp. 306-19.

[7] Hagen, *op. cit.*, p. 84.

[8] *Ibid.*, p. 85.

[9] Gardner, W. R., "Dynamic Aspects of Water Availability," *Soil Science*, Feb. 1960, 89: 63-73.

[10] Rhoades, H. F., and L. B. Nelson, "Growing 100 Bushel Corn with Irrigation," *Water-Yearbook of Agriculture, 1955* (Washington: Govt. Print. Off.) pp. 394-400.

[11] Stanhill, G., "The Effect of Differences in Soil Moisture Status on Plant Growth: A Review and Analysis of Soil Moisture Regime Experiments," *Soil Science*, Sept. 1957, pp. 205-14.

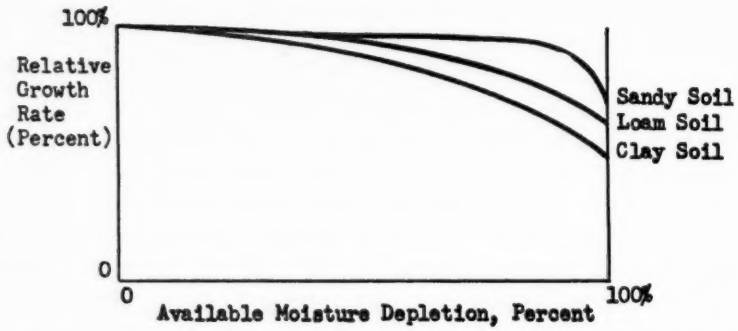

FIGURE 1. VARIATIONS IN HOW RELATIVE GROWTH RELATES TO AVAILABLE MOISTURE DEPLETION FOR SANDY, LOAM, AND CLAY SOILS.

well as rooting distribution, intensity of transpiration rates and other factors (see Figure 1). The soil moisture stress-availability curves are constructed by inverting soil moisture release curves as they relate to available moisture depletion between field capacity and permanent wilting point. If the researcher can determine these curves he can express relative growth as a function of available moisture depletion for each soil. In other words, we are attempting to estimate the productivity of the moisture in the root zone. In doing this we must, as in any other single input production function, hold all other variables constant except water and the bundle of inputs that go along with it such as irrigation labor and power to pump the water. We are not at this time trying to measure the substitutability of other inputs for water.

Further Assumptions

With this brief review, it is possible to proceed with an analysis of the mean moisture stress theory and how it can be fitted into a model which can be used to estimate production functions for crops using irrigation water. To do this, the following simplifying assumptions are made:

1. The farmer has complete knowledge of the amount of soil moisture present at any given time.

2. The relative potential growth of the plant part to be harvested is linear over time from zero to time of harvest, or at least throughout the irrigation season. (Actually this relationship is usually expressed as a sigmoid curve.) Thus, the effect of soil moisture stress on total relative growth is assumed equal between irrigation cycles regardless of the evapotranspiration rate. This means that if the available moisture is reduced to the same point in two different irrigation cycles, the reduction in relative growth will be the same in each. (This assumption is not necessary if actual growth curves are available.)

3. As a first approximation, soil moisture stress will have an equal effect upon plants that are harvested for their green weight, dry weight, or fruit weight and size. A correction for this assumption can be made if the relationship between soil moisture stress and these various aspects of harvestable yield is available. The effect will be resolved in the yield of the fruiting or seed portion of the plant even though the stress period occurs prior to the setting of the fruit.

For purposes of a general model we abstract from certain variables—factors such as the micrometeorology of the growing site, variations in rooting distribution due to soil type, minor variations in cultural practices and differences in harvesting methods. These factors can have an effect on the end product, but only a qualitative recognition can be made of them here.

The assumption as to linearity of growth over time serves to simplify the precise effect of extreme moisture stress at each stage of plant development. The assumption of inverse relationship between plant growth and the mean moisture stress is a simplifying one; it assumes away some of the minor factors that, although present, will change the end results but little.

Procedure

Briefly, the procedure to be followed in this analysis is to use the moisture release curve for a specific soil as an indicator of the relative growth rate of a plant grown on that soil. Applying some elementary mathematics, an index of relative plant growth is derived. Multiplying this index times estimates of potential yield provides actual yields under specified irrigation practices. The specified irrigation practices are included as constraints in a water budget table to obtain the labor and water requirements for the crop under consideration. By attaching prices to these inputs and outputs a value is established for the water used in the irrigation cycle.

The procedure in more complete detail is as follows: As stated earlier, the moisture releasing characteristics curve which describes the amount of moisture than can be made available to plants within the range from field capacity to P.W.P. can be determined. Once this curve is known, the analyst can estimate the relative plant growth rate for an irrigation cycle when the terminal moisture depletion percentage is specified. This is done by taking the area under the moisture release curve (the integral) as a fraction of the total area of the rectangle described by the terminal moisture depletion percentage and the potential growth line. This fraction is the index of growth rate for a plant for one irrigation cycle (see Figure 2).

For example, taking the relative moisture depletion of 80 percent as a terminal point for an irrigation cycle, the area under the curve between

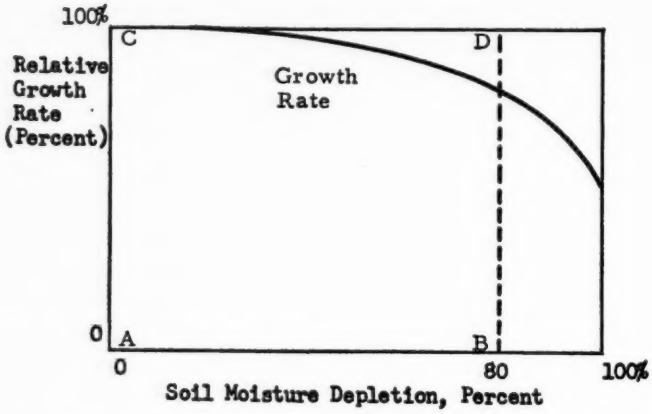

FIGURE 2. RELATIVE GROWTH AT DIFFERENT LEVELS OF SOIL MOISTURE DEPLETION (HYPOTHETICAL DATA).

0 and 80 as a fraction of the area of the rectangle *ABCD* in Figure 2 will give the index of relative growth for one irrigation cycle.

We assumed earlier that each irrigation cycle is independent of all others; as a consequence it is possible to describe the relative growth over the entire irrigation or growing season as in Figure 3. It shows that the growth rate decreases as the available moisture is depleted within each irrigation cycle; from t_0 to t_1 the available moisture is depleted; then water is again applied and the soil is returned to field capacity. This process is repeated until harvest. (The mathematical equations for this approach appear in the appendix for those interested.)

If we apply the relative growth pattern of Figure 3 to the assumed linear potential growth function, we can evaluate growth by irrigation cycles and for the entire season (see Figure 4).

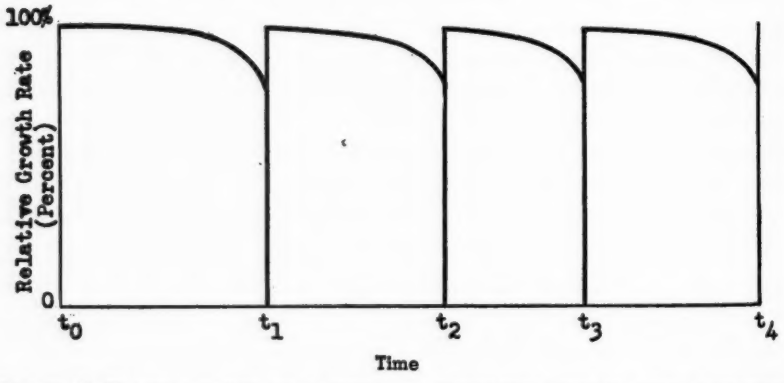

FIGURE 3. PLANT GROWTH IN A SERIES OF IRRIGATION CYCLES WITH TERMINAL MOISTURE DEPLETION POINT HELD CONSTANT.

Up to now, our objective has been to develop a procedure for estimating the growth of a crop conceptually when the terminal depletion point of soil moisture is given, whether this point is constant or changes from one cycle to another. The next step is to apply the procedure in the preceding sections to a particular crop.

Soil scientists can with a fair degree of reliability measure the amount of available moisture between field capacity and P.W.P. for any soil with the tools now available. Data are also available on evapotranspiration rates by months in different geographical locations for many crops. If the actual evapotranspiration rate data are not available they can be esti-

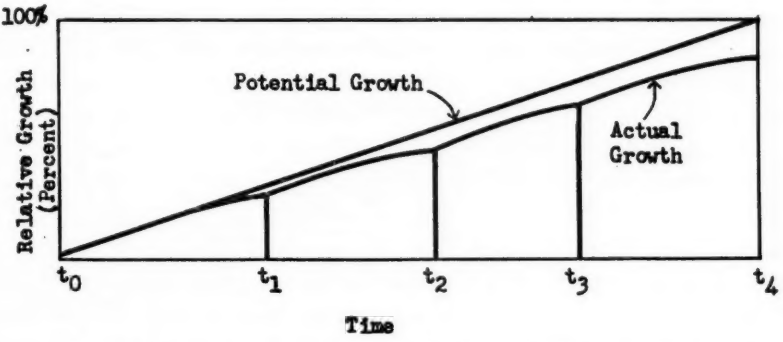

FIGURE 4. ACTUAL AND POTENTIAL GROWTH BY IRRIGATION CYCLES.

mated using the Blaney-Criddle Formula[12] or another appropriate method of determining water use of crops.[13]

Physical inputs associated with terminal moisture depletion points also can be estimated; a simple bookkeeping technique will serve this purpose (see Table A). The technique used to construct Table A is not a new one to researchers dealing with irrigation practices. It is based on the idea that the soil in the plant's root zone is a storage reservoir for moisture. The amount of moisture contained in a foot of soil depth varies with the soil type. As evaporation takes place and the plant transpires, the amount of moisture in the root zone is reduced. When the moisture in the soil reservoir is depleted, additions in the form of rainfall or irrigation water must be made to bring the root zone back to field capacity.

The water budget is used for two purposes: (1) to determine the dates and number of irrigations necessary for a particular crop on a given soil within the constraint of a specified terminal moisture depletion percent-

[12] *Determining Water Requirements in Irrigated Areas from Climatological and Irrigation Data*, U.S. Soil Conservation Serv., SCS-TP96, 1950.

[13] Halkias, N. A., F. J. Veihmeyer, and A. H. Hendrickson, "Determining Water Needs for Crops from Climatic Data," *Hilgardia* (Berkeley: Dec. 1955), vol. 24, no. 9, pp. 207-33.

TABLE A. EXAMPLE OF AN IRRIGATION WATER BUDGET: HESPERIA FINE SANDY LOAM, COTTON, 100 PERCENT DEPLETION (ALL FIGURES IN INCHES)

Month	Root zone depth (in ft.)	Inches available water		New root zone (in ft.)[b]	Evapotranspiration rate per day	Carryover[c]	From new root zone[d]	Moisture at start of period[e]	Additions[f]	Total available[g]	Withdrawal[h]	Moisture at end of period	Irrigation dates
		per ft. of soil	root zone[a]										
1	2	3	4	5	6	7	8	9	10	11	12	13	14
April* 16–30	.75	1.25	.94	0	.020	0	.94*	.94	0	.94	.3	.64	
May 1–15	1.00	1.25	1.25	.25	.060	.64	.31	.95	0	.95	.9	.05	
16–31	1.50	1.25	1.87	.50	.080	.05	.62	.67	1.87	2.54	1.2	1.34	May 25
June 1–15	2.00	1.25	2.50	.50	.167	1.34	.63	1.97	2.50	4.47	2.5	1.97	June 12
16–30	2.50	1.25	3.12	.50	.213	1.97	.62	2.59	3.12	5.71	3.2	2.51	June 28
July 1–15	3.00	1.25	3.75	.50	.307	2.51	.63	3.14	3.75	6.89	4.6	2.29	July 10
16–31	3.33	1.25	4.16	.33	.313	2.29	.41	2.70	4.16	6.86	4.7	2.16	July 23
Aug. 1–15	3.67	1.25	4.59	.33	.267	2.16	.41	2.57	4.59	7.16	4.0	3.16	Aug. 10
16–31	4.00	1.25	5.00	.33	.253	3.16	.41	3.57	5.00	8.57	3.8	4.77	Aug. 30
Sept. 1–15	4.00	1.25	5.00	0	.147	4.77	—	4.77	—	4.77	2.2	2.57	—
							4.98		24.99		27.4		

* Assumes preplanting irrigation to bring soil to field capacity.
[a] Moisture available in root zone when soil is at field capacity (col. 2×col. 3).
[b] Addition to root zone due to expansion of roots into new soil.
[c] Moisture left in root zone at end of previous time period (amount in col. 13 for last time period).
[d] Moisture available to plant from new root zone (col. 5×col. 3).
[e] Col. 7+col. 8.
[f] Moisture added to soil by irrigations to bring soil back to field capacity (from col. 4).
[g] Col. 9+col. 10.
[h] Evapotranspiration rate per day times number of days in time period.
Data in columns 2, 3, and 6 must be obtained from outside sources such as agronomists and irrigation personnel.

age, and (2) to determine the amount of water needed to refill the soil reservoir for each irrigation.

Changes in the terminal moisture depletion levels between irrigations could be taken into account in Table A by varying the water available per foot of soil depth. For example, a soil with a water holding capacity of 1.25 inches per foot of depth would be reduced to 1.00 inch if the depletion level were allowed only to go to 80 percent of available moisture. In Table A the terminal moisture depletion level is held constant at 100 percent. The total of the additions (Column 10) for the season is a net figure representing water entering the soils. It must be divided by the expected irrigation efficiency to get the total amount to be applied.[14] Differences in total water requirements above total consumptive use depend upon irrigation efficiency. The user can modify this method in humid areas by dividing Column 10 into two parts—one for rainfall and one for irrigations.[15] The total of "withdrawals" (Column 12) less the amount in Column 13 for the last time period should balance with the total "from new root zone" (Column 5) plus the total of Column 10. We can use estimates by agronomists of total potential yields when water is not limiting and multiply by the index of expected yield under specific irrigation practices to obtain actual yields.

Rooting characteristics of plants vary widely among soils. The rooting patterns of a specific plant will be different in a shallow soil underlaid with a hardpan than in a deep well-drained soil. Information on these variations is available in published form and must be considered to keep the analysis realistic.[16]

The shape of the root development of most field crops is conical. New root zone is brought into the analysis in incremental steps in this analysis; therefore some arbitrary depth less than total rooting depth is necessary to compensate for that space where no roots exist. Note area above the curve in Figure 5; percent moisture extraction is measured on the *Y*-axis, and soil depth on the *X*-axis. For the purpose of this paper, the third quartile moisture extraction depth was used; that is, the depth at which 75 percent of all moisture is extracted.

As the plant grows and transpires, the soil moisture in the root zone is depleted, but at the same time the root system is expanding into a new moist soil. Hence, the selected zone of depletion varies with plant growth.

[14] It should be noted that no accounting has been made for the time and the effect on growth for the short period following irrigation when the soil is saturated. However, this time is so short (36-48 hours) that it could be ignored for the sake of simplicity and ease of calculation.

[15] Rainfall must be entered in Column 10 as effective rainfall to take into account surface runoff.

[16] Weaver, J. E., *Root Development of Field Crops* (McGraw-Hill Book Co., New York: 1926). Also, Doneen, L. D., and J. H. MacGillivary, *Suggestions on Irrigating Commercial Truck Crops,* Calif. Agr. Expt. Sta. Mimeo (Berkeley: 1946).

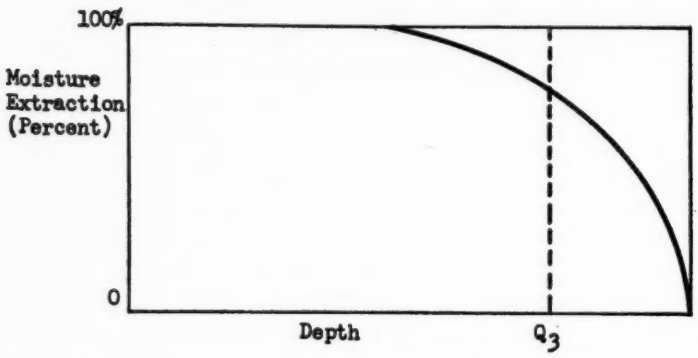

FIGURE 5. SOIL MOISTURE EXTRACTION CURVE (HYPOTHETICAL PLANT).

How the Method Operates

An actual example will further illustrate how this method works with empirical data and how the user may interpret his results (see Table B).

Cotton grown on Hesperia Fine Sandy Loam.

Terminal moisture depletion percent: 100 percent for each irrigation cycle, giving an index of growth of 87.

Potential yield: 2.5 bales × 87 Index of growth = 2.17 bales of lint (and .97 ton seed).

Gross income per acre at 1958 prices	$418.07
Variable costs per acre less water cost	205.25
Net variable income per acre	$212.82

The object of Table B is to show within the framework of the hypotheses that there is a different production function for water for each irrigation cycle. It is possible to attach a value to the water used in each cycle. As shown in Table B, the net variable income per inch of water decreases as the growing season progresses until the fifth irrigation cycle; it then increases until the end of the season except for the last cycle.

These results are close to what could be expected if the assumption of linearity of growth over time, as shown in Figure 5, had been replaced with a sigmoid curve. Using a sigmoid curve would have reduced the return to water in the last two irrigation cycles and increased the return in third and fourth irrigation cycles.

Optimizing Model

One other critical question remains unanswered: "When is the optimum time to apply irrigation water?" We obtain the curve shown in Figure 6 if we plot I_o (the index of relative growth) for the entire range of possible

TABLE B. INPUTS AND NET VARIABLES RETURNS FROM WATER BY IRRIGATION CYCLE COTTON, HESPERIA FINE SANDY LOAM SOIL WHEN TERMINAL MOISTURE DEPLETION IS 100 PERCENT[a]

Irrigation cycle	Number of days in cycle[b]	Percent distribution of days	Net variable income except water cost[c]	Acre inches water applied[d]	Net variable income per acre inch	Water cost at $10/ac. ft.	Net variable income
Preirrigation	40	25.9	$55.12	6.67	$8.26	$5.56	$49.56
1	18	11.7	24.90	3.12	7.98	2.60	22.30
2	16	10.4	22.13	4.17	5.31	3.47	18.66
3	13	8.4	17.88	4.80	3.73	4.00	13.88
4	13	8.4	17.88	5.77	3.10	4.81	13.07
5	18	11.7	24.90	5.94	4.19	4.95	19.95
6	20	13.0	27.67	6.56	4.22	5.46	22.21
7	16	10.4	22.13	6.67	3.32	5.56	16.57
Total	154	100.0	$212.82	43.70	—	$36.41	$176.41

[a] Index of growth equals 87 percent, potential yield 2.5 bales.
[b] Irrigation season runs from April 15 to September 15 (see Table A).
[c] 1958 price levels; does not include fixed costs.
[d] Based on Table A; average irrigation efficiency 67.5 percent.

I_θ's or levels of moisture depletion for the relative growth curve (see Figure 2). This curve is ordered similarly to the relative growth rate curve from which it was derived.

By multiplying the I_θ times potential growth times price we obtain a gross income curve with the same shape. This income curve has some unconventional features; it is in terms of soil moisture depletion, not in terms of water used as in the usual input-output model. A critical point

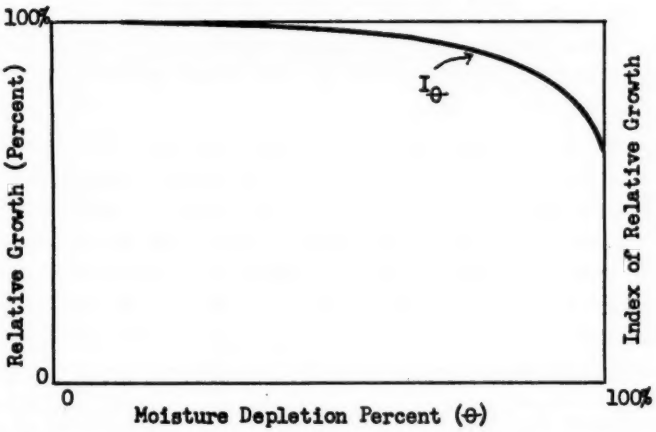

FIGURE 6. ACTUAL GROWTH AS A PERCENT OF POTENTIAL GROWTH FOR A SINGLE IRRIGATION CYCLE.

here is that for any irrigation cycle, as the soil moisture is allowed to be depleted over time, it requires more and more water to return the soil in the root zone to field capacity (because the size of the soil reservoir to be filled increases as the volume of roots increases).[17]

The relationship now is one of an increasing cost curve and a decreasing revenue curve over time. It is convenient at this time to keep the relationship in positive terms by inverting the revenue curve. The result is a curve of income *foregone* as related to increasing soil moisture depletion. That is, income is *lost* when the soil moisture is not maintained at a level where 100 percent of potential growth is obtained.

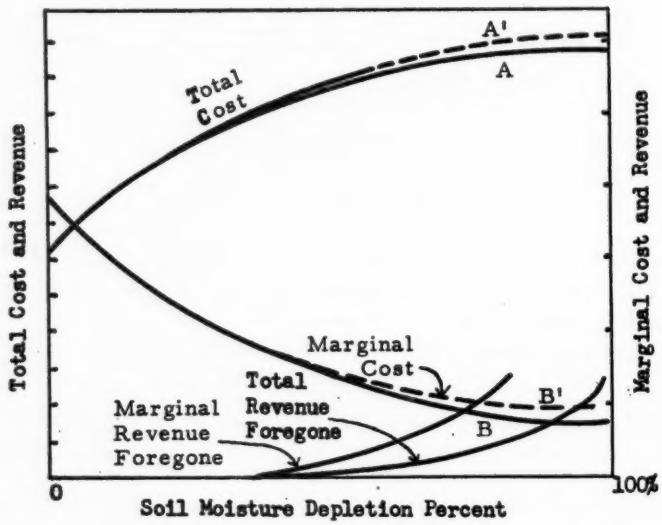

FIGURE 7. INCOME FOREGONE AND IRRIGATION COSTS AS RELATED TO SOIL MOISTURE DEPLETION FOR ONE IRRIGATION CYCLE (HYPOTHETICAL DATA).

The marginal cost and marginal revenue *foregone* curves used in this analysis and depicted in Figure 7 are not the same as appear in traditional economic analysis; they relate to soil moisture depletion, and only indirectly to the output, in sharp contrast to normal usage. However, the principles involved in input-output analysis still hold true. The net variable income is at a maximum at the intersection of the marginal cost curve and the marginal revenue *foregone* curve. The optimum point to which the available moisture should be allowed to deplete, in other

[17] It is relevant here that it is impossible to wet a given volume of soil to less than field capacity. If only a small amount of water is applied then only the surface area will become wetted. As more water is applied, the soil at progressively lower depths will become wetted to field capacity.

words, is where the *marginal cost of irrigation* is equal to the *marginal revenue foregone* with respect to moisture depletion.

Curves *A* and *B* in Figure 7 will shift to a higher position as the season progresses due to the increased amount of water required; this change is depicted by curves *A'* and *B'*.

The economic criterion of irrigating when marginal cost equals marginal revenue foregone holds for each irrigation cycle. However, as shown in Figure 7, this condition will not result in the same terminal moisture depletion percent for each cycle. In fact, it could vary over a rather wide range if the cost of pumping water increased through the season and the expected commodity price varied during the growing season.

Conclusions

For many years, economists working in irrigated agriculture have spoken in terms of water requirements for crops rather than farmer demand for water. When these economists attempt to fit a production function to agronomic data they are able to measure the value of water at only one point on the production surface. This situation has resulted from two errors: (1) misinterpreting the results of irrigation experiments due to a lack of understanding of the basic underlying plant-soil water theory, and (2) using only total annual water inputs in their data. This paper has attempted to show that there is a production function for each irrigation cycle and total output can be estimated only by taking into account the plant-soil water relationship within each irrigation cycle. From the discussion of this theory it can be seen that when the terminal moisture conditions for *each* irrigation cycle are not taken into account, relating yield to *total* water applied during the season has little meaning.

It will be possible, using the approach outlined in this paper, to take into account not only the physiological relationships within each irrigation cycle but also intraseasonal variations in the supply and cost of water. As was shown earlier, it is also possible to place a value on the water used in each one of these irrigations.

This approach, as stated earlier, is a first approximation; there have been many adjustments, assumptions and approximations made to put this theory into an operational form. Because of these shortcomings it is recognized that there is much need for further refinement in the data, especially in the area of the nature of the effect of different amounts of soil moisture stress in different time periods upon production of different plant parts and the effect of moisture stress on the different stages of plant development. This approach does have the virtue that as more is learned about some of the data gaps, assumptions can be replaced by precise knowledge and the analysis improved accordingly.

Mathematical Appendix

For one irrigation cycle relative growth is the area under the moisture release curve, as follows:

$$Gr_i = I_{\theta_i} \tag{1}$$

where Gr is the relative growth during the ith irrigation cycle expressed as a percent of potential growth, or

$$Gr_i = \frac{\int_0^{\theta_i} g(x)dx}{\theta_i \times 100} = I_{\theta_i} \tag{2}$$

where I is the fraction of potential growth for one irrigation cycle, θ_i is the moisture depletion percent at which the irrigation cycle is terminated, and $g(x)$ is the functional relationship of relative growth to percent moisture depletion.

For an entire irrigation season we have:

$$Gr = \sum_{i=1}^{n} I_{\theta_i} \frac{t_i}{T} \tag{3}$$

where t_i is the length in days of the ith irrigation cycle and T is the length in days of the irrigation season.

For the special case where θ_i is constant for each irrigation cycle throughout the season, we have:

$$Gr = I_{\theta_i} \left(\sum_{i=1}^{n} \frac{t_i}{T} \right) = I_{\theta_i} \tag{4}$$

because for the entire season

$$\sum_{i=1}^{n} \frac{t_i}{T} = 1 \tag{5}$$

USE OF DATA FROM CONSUMER FOOD PURCHASE PANELS IN MARKET DEVELOPMENT RESEARCH

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THIS paper is concerned with the use of data from consumer food purchase panels in market development research. The purchase panel is only one of a number of alternative sources of data for market development research. It provides some unique information, has some advantages over alternative techniques for collecting some types of data and has a number of unique problems or limitations as a data-collecting tool.

It should be emphasized that the panel is simply a means of collecting data and not an approach to research. It is important that market development research problems first be conceptualized independent of data-collecting techniques and then be modified to fit the practical problems of data, rather than that the research be initially designed to use a particular type of data. To conceptualize the problems in terms of particular data-collecting techniques can only result in reducing the scope and the creative contribution of market development research.[1]

The consumer purchase panel technique is typified by the collection of purchase data on a repetitive basis over time from the same families. The data are supplied by means of a diary form kept by a responsible member

* I wish to acknowledge the contribution of Dr. G. G. Quackenbush to this paper, which is partially based upon cooperative inquiries made in the process of developing and operating the MSU Consumer Panel.

Louis Fourt of the Market Research Corporation of America also supplied for my use several reports from M.R.C.A. dealing with the use of panels in market development research.

[1] In discussing an earlier version of this paper Louis Fourt made the following relevant comment concerning this point:

"Market development inherently is a dynamic subject. As a dynamic study area, it can best be studied with dynamic data, treated with dynamic tools of analysis. It is this point of view that causes me to quarrel a little with Prof. Shaffer's emphasis that consumer panels are *means* to research objectives which should first be independently conceptualized.

"The problem is that researchers know too little of the existence and potential availability of panel data, its quality, and the tools that are available for its use. Consequently, all too often panel data are not considered in connection with a problem, or are used essentially as still snapshots instead of being used as a moving picture of consumer behavior.

"Worse, problems may not be considered as proper research objectives because interested researchers do not believe suitable data and analytical methods can be made available . . . until highly qualified researchers from several backgrounds earnestly examine panel data as a dynamic stream of information about the behavior of identifiable consumers and push its analysis close to its ultimate limits, we will not solve some of these fascinating dynamic problems in consumer behavior." Proceedings of First National Symposium on Dairy Market Development (Chicago: American Dairy Association), 1960, pp. 99-100.

of the family and usually mailed to the sponsoring organization. In addition to purchases, respondents may report a great variety of additional information, from socioeconomic and psychological characteristics of the family to exposure to mass media. Purchase data may include prices, expenditures, quantities, method of preservation, size of package, number of units purchased at one time, type of store and date of purchase and, perhaps, use of product.

There are other types of panels which may be useful in market development research. One of these is the product testing panel, which reacts to products of various types and may yield very useful consumer acceptance information in respect to product characteristics, package design, size of units, pricing etc. However, the repeated use of a product testing panel is usually a matter of economy and not a source of information which could not be obtained simply from individual sample surveys. Another type of panel providing data useful in market development research is the listening, viewing or readership panels which report exposure to advertising in the various mass media. Panels have also been used for collecting financial data, purchases other than food, expectations and attitudes toward the purchases of durables, and farm purchase and sales data. These other types of panels may provide data useful in market development research; however, this paper deals only with the continuous consumer food purchase panel reporting by diary form.

The Food Purchase Panel as a Source of Data

The unique character of panel data

The major alternatives to the food purchase panel as methods of collecting purchase data are the one-time recall survey, aggregate production or sales data, store audit data and store experiment data.

Each of these provides unique and useful data for market development research. The unique aspect of panel data centers around the fact that the purchase data are identified with individual families through time. The one-time recall survey also identifies purchases with families but can provide little time dimension.[2] The aggregate and store techniques can provide the time sequence, but do not relate the purchase to the family buying.

The panel appears unique as a data-collecting technique by providing the following types of data:

1. It provides data showing changes in purchases related to changes in characteristics of individual families through time.

[2] The recall survey is one in which the respondent is asked to report past events from memory. It is difficult for many respondents to recall food purchases accurately for even the past week, let alone extending the period of recall beyond a week. It is, of course, possible to obtain a time dimension by means of repeated recall surveys, moving in the direction of a purchase panel.

2. It provides data relating purchases of different products for identifiable families through time.
3. It provides data showing a sequence of purchases for individual families.

There are also other characteristics of panel data which are more or less unique. It is, for example, possible through a series of successive interviews over time, to obtain a quantity of data from an individual family which cannot ordinarily be obtained from one-time surveys. Thus, it is possible to have more socioeconomic and psychological variables available to relate to purchase behavior than is possible by other means.

The panel can provide data for short time intervals—periods of one week or a month—for time series analysis. This type of data is not usually available to form aggregate time series. Also, because the panel is in continuous operation, it is possible to provide very rapid reports where timeliness is important.

The panel, of course, also can provide much data that is not uniquely different from that which might be obtained by other means. It may be more or less expensive or more or less accurate but not unique.

Accuracy of data

One of the significant problems in market development research is obtaining accurate data. Unfortunately, alternative techniques of collecting purchase data frequently provide different estimates. Rather than discuss this area in detail, I will merely outline the problem and give some general conclusions.[3]

The problem of accuracy of data from a panel falls into two broad problem areas: (1) Obtaining and maintaining a representative sample over time and (2) Errors in reporting.

It is not possible to obtain and maintain a perfect probability sample for a continuously reporting panel. Keeping records of purchases is work or at least inconvenient (even if an agent comes to the house to help with the record), and not everyone is willing or able to cooperate. It is, however, possible to maintain, with proper incentives and procedures, a sample with characteristics very similar to those of the parent population. However, if cooperators and non-cooperators are inherently different, it is impossible to obtain a representative sample. It should be recognized that all samples of consumers have problems of non-cooperation or non-representativeness. A carefully done panel sample will probably be more representative than many less carefully done interview surveys.

[3] See G. G. Quackenbush and J. D. Shaffer, *Collecting Food Purchase Data by Consumer Panel*, Mich. Agr. Expt. Sta. Tech. Bull. 279, Aug. 1960, for further detail.

The panel presents an additional problem in maintaining a representative sample, the problem of conditioning. The evidence is that keeping records of food purchases over a long period of time does have a limited influence on the purchasing pattern of the family. My own opinion is that this may be serious where the panel deals with a limited number of items, but that it will have only minor effects on a family reporting on a large number of items such as all food.[4]

The problem of errors in reporting is common to all survey techniques. A recall survey will usually provide substantially larger estimates of purchases than a panel. Aggregate data and store studies, when they are available, will tend to fall in between the two. Recall surveys apparently are subject to a substantial telescoping effect resulting in overestimation.[5] Panels are apparently subject to some loss through forgetting, etc.[6] On the whole, however, the panel appears to provide more reliable and consistent results than the recall survey and may be superior to a number of aggregate estimates.

As in most research, certain details are of crucial importance in getting accurate reports. Research, for example, shows that the type of diary and the length of the reporting time can significantly influence the accuracy of reports.[7] Other procedures are also important.

Use of Panel Data in Answering Market Development Questions

It is probably true that there is a good deal more art than science in market development. Much of the contribution of market development research is in the areas of providing background information, researching suggestions and clues, raising questions and evaluating actions which are taken. Scientific methods may be used in obtaining this data but its use is in the art of market development. Market development research, at the current state of development at any rate, will seldom provide definitive answers to the basic market development questions:

(1) What is the optimum product design and mix?

(2) What is the optimum advertising program?

(3) What is the optimum combination of retail merchandising techniques?

[4] *Ibid.*, pp. 23-28.

[5] Telescoping refers to the tendency for respondents to report purchases from previous periods as purchases during the reporting period in a recall survey.

[6] *Ibid.*, pp. 28-32, 35-44. Also Daniel B. Levine and Herman P. Miller, *Response Variation Encountered with Different Questionnaire Forms*, U.S.D.A. Marketing Res. Rept. No. 163, pp. 16-18; Joseph F. Metz, Jr., *Accuracy of Response Obtained in a Milk Consumption Study*, Cornell Univ., July 1956.

[7] James D. Shaffer, "The Reporting Period for a Consumer Purchase Panel," *J. of Marketing*, 19:252-57, Jan. 1955, and Harrie F. Lewis, "A Comparison of Consumer Responses to Weekly and Monthly Purchase Panels," *J. of Marketing*, 12:449-54, April 1948.

(4) What is the optimum distribution pattern to maximize sales? However, market development research can provide information which should contribute to better answers to these basic questions.

The following is a list of ten more specific questions which appear relevant to market development. Following each question is a brief comment or example concerning the possible use of consumer panel data in seeking the answer.

1. Is there an unexploited segment of the market which may be reached by developing a new product or altering the characteristics of existing products?

Panel data can only make a limited contribution to this question by identifying heavy and light uses of products, and perhaps supplying data indicating products which are frequently substituted for the product of concern.

For example, M.S.U. panel data indicates that 20 per cent of the families buy about 90 per cent of the buttermilk, 95 per cent of the chocolate milk, 97 per cent of the half and half, 91 per cent of the Swiss cheese, etc. It would be possible to identify these heavy users and their light using counterparts both in terms of characteristics and purchases of other products.[8]

2. What is the potential long run market for a new product?

Estimating the potential market for a new product based upon a test market or early results of broader distribution can be substantially improved by use of panel data. The simple sales data from a market test are not sufficient since they do not differentiate between first purchases and repeat purchases. The panel data, by showing repeat purchases and the length of time between purchases, provide unique data for early prediction of potential market.[9]

3. Does a new or modified product add to total sales or simply substitute for another product of the firm or industry?

Panel data, by providing observations of purchases before and after introduction of the new product for individual families, supplies information on substitution patterns. It is frequently difficult to distinguish such substitution from aggregate data due to the many other influences usually present in a market affecting the sales data.

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[8] The M.S.U. Consumer Panel was a consumer purchase panel representative of Lansing, Michigan, reporting purchases of all food from 1952-1958.

[9] Louis Fourt and Joseph Woodlock report on a predicting model using this type of data in "Early Prediction of Market Success for New Grocery Products," *J. of Marketing*, Oct. 1960.

An example of such a study was made using M.S.U. panel data where it was found that when fluid skim milk sales increased about half of the additional fluid skim milk purchases served as a net increase in total fluid milk sales and half was simply substituted for other fluid milk products.[10]

From an industrial point of view, it is particularly important to determine these substitution relationships since adding new products adds to costs and if it does not significantly add to total sales, it may reduce rather than increase net income to the industry.

4. Would offering products in a different combination of sizes of packages alter the amount purchased?

It is important to have the minimum number of sizes of packages consistent with effective market coverage since each additional package usually adds to packaging and other marketing costs.

Panel data may provide some circumstantial evidence relating to this problem by showing the frequency distribution, amount of products purchased at one time, the combinations of sizes purchased at one time or for a time period, frequency of purchases and a low frequency of customers among certain size-of-family groups.

For example, if practically all families buy two of a smaller size or one of a larger size package, it would probably be possible to eliminate the smaller package without loss of sales. If households of one and two members very seldom buy a product it may indicate that the smallest package available is too large for them and they avoid the product because they waste part of it by having to buy too large a quantity at one time. (Of course, the fact that they do not buy may be due to another reason unrelated to package size.)

The panel may also provide supplementary data from a test market by showing the pattern of purchases over a period of time for a complete market. A package innovation may simply take sales from another time period or in the case of limited store coverage, from one store to another. It is because of these possibilities that additional consumer-related information is needed to evaluate store experiments for packaging products and other merchandising innovations.

5. Will a newly designed package alter sales?

Here again panel data might make a limited supplementary contribution in analysis of a test market trial. In terms of brand competition the panel would show comparative sales of brands and brand switches relative to package innovations among competitors.

[10] G. G. Quackenbush and J. D. Shaffer, "Competitive Relationships of Fluid Skim Milk and Fluid Whole Milk," Mich. State Quart. Bul., Art. 38-31, Aug. 1955.

6. To whom should advertising be directed? What type of advertising message will be most successful?

Both one-time recall surveys and panel data can be used to identify users and nonusers and heavy and light users of particular products. This information should certainly be known to the advertiser, but it does not tell him at whom to aim his advertising. A test market situation might be used to attempt to measure the differential effect of advertisement directed at heavy using groups as compared with groups using the product lightly. Advertisements designed for an immediate and short run impact might be evaluated. However, since the short run influence of an advertisement may be very small and because there are so many subjective and uncontrolled variables present, it is very uncertain that meaningful information could be obtained for many types of ads.

A study of purchase patterns—including the pattern of purchases of substitute products—from panel data might provide the creative advertiser information useful in determining groups with highest potential response to advertising and give some clue to types of messages which might be effective. Certainly the advertiser should know the concentration of purchases among families—i.e., a product for which 90 per cent of the purchases are made by 10 per cent of the families requires quite a different treatment than one with a much broader market.

As a general rule, heavy and light users have only been identified in terms of a limited number of demographic and economic characteristics. For advertising purposes it may be more important to identify families in terms of psychological and sociological variables. For example, knowledge of a buyer's self and role concepts, personality traits, beliefs and attitudes may be useful in devising an effective advertisement. Because of the possibility of obtaining large amounts of data from panel members over time, a panel might be used more effectively than a one-time survey to identify heavy and light purchasers in terms of these variables. We have done some work which indicates that it is possible to obtain personality and role-self scales from fairly random samples of families.

Perhaps a psychological test could be devised to indicate the degree of susceptibility to advertising and this measure used to help decide at whom to direct major advertising efforts.

A word of caution should be included, however, in respect to tieing these psychological variables to a purchase panel. Two difficulties are created. One is that excessive questioning in these areas may contribute to the problem of conditioning. The other is that while the panel might be representative in terms of demographic and consumption variables, it may not be representative in terms of psychological variables. A test of the M.S.U. consumer panel found a significant difference between the

panel and a random sample in terms of some role and self perceptions.[11]

7. Which media should be used to carry the advertising?

It is possible to obtain diary records of both purchases and media exposure and this combined data should offer some assistance in selecting media. Heavy and light users of products can, for example, be identified according to the magazines they subscribe to. Thus, once it is decided at which group an ad is to be directed the data should be valuable in selecting the media which would carry the message most efficiently.

8. Which products of an industry or firm will respond best to advertising?

This is an important question for a multiple product industry such as the dairy industry. It has sometimes been argued that products with higher price or income elasticities of demand are more responsive to advertising. There might be something to this, all other things being equal, but it is the other things which are not equal which are most likely to determine the effectiveness of advertising. Some elementary factors such as uses not known by many consumers, a particularly good advertising theme, etc., are probably most important in determining the allocation of the advertising dollar among products. Panel reports of food utilization, as the Market Research Corporation of America National Household Menu Census might be cited here as a unique source of information on food uses.[12]

Again panel data may make a marginal contribution to the answers to this question by providing basic information on purchase patterns and possibly in terms of market testing of local advertising. For example, a very rough analysis correlating newspaper advertising and meat purchases by M.S.U. Consumer Panel families indicates a considerable difference in response to the advertising among the meats studied.[13]

9. What is the potential of alternative merchandising deals or innovations? What effect did a particular merchandising deal or innovation have on sales?

Panel data showing frequency and quantities purchased may give some clue as to the potential of some types of merchandising deals. However, panel data may be especially valuable in evaluating a merchandising deal or innovation by showing the longer run effect of the deal for the total market. Merchandising innovations evaluated simply on the basis of ex-

[11] Mich. Agr. Expt. Stat. Tech. Bull. 279, pp. 15-66.

[12] The M.R.C.A. Menu data are based upon 14-day diary records from a national sample of 3,989 homes representing the United States. The sample was so rotated in terms of time as to represent the 12 month period ending June 30, 1958.

[13] Merrill M. Parsons, *Newspaper Advertising of Meat Products and Its Relation to Consumer Purchases in Lansing, Michigan, During 1956*, unpub. Master's thesis, Mich. State Univ., 1958.

perimental data from stores may be quite misleading in that purchases may simply be shifted between stores or from one time period to another. Panel data, by showing the pattern of purchases over time from all sources, can be the basis of a much more complete evaluation. One of the important questions is, of course, did it cause any non-buyers to purchase and did these families make repeat purchases? Only panel data provides the basis for this type of analysis.

10. Does the present distribution system maximize availability and sales?

This question may frequently be left out of the area of market development research, although it may be one of the most important. For many products the degree or ease of availability may be the most important factor in total sales. Similarly, some types of retail outlets may be much more effective in selling a particular product than others. Panel data may be used to identify sources of purchases of a particular product and of substitution and complements which should aid in evaluating the system.

Panel data may also contribute to an evaluation of alternative outlets such as, for example, home delivery and store sold milk. The simple finding that families buying by home delivery buy more than those buying at a store does not prove the case for home delivery. It may simply be that those families which buy smaller quantities of milk are more likely to buy at stores. Panel data is not likely to provide a definitive answer to this question, but can provide information leading to a somewhat better insight through massing data showing changes in purchase patterns when the source of purchase changes.

A panel technique which might be of considerable value in evaluating advertising and other market development activities is the use of matched city panels. This technique, to my knowledge, has received little use. The idea is to establish purchase panels in each of two closely comparable cities using one as a control and experimenting in the other.[14]

There are, of course, additional questions to be answered by market development research, such as: Was an advertising program successful? and, How much should be spent on advertising a particular product? The above list was not meant to be exhaustive, but was used to indicate something of the scope and potentials of panel data in market development research. It shows that panel data can make some unique contributions, but that in many cases its contribution to the answer of important market development questions is quite marginal. Properly used it is one of the useful tools for market development research. It must be considered in terms of its cost and its possible contributions to specific problems.

[14] The panels operated by the North Carolina and Georgia Experiment Stations might serve this function for some general agricultural products. Market Research Corporation of America has 7 metropolitan panel samples within their national sample which can offer comparative data.

NOTES

PHILOSOPHY, METHOD AND STATUS OF AGRICULTURAL ECONOMICS*

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> The men whom some economists thus tend to despise they call "methodologists." Perhaps they should be despised. What is the use of a man who studies scientific method? He may explain to students how scientists reached their new theories, but this is unlikely to help the students reach new theories of their own. He may generalize, and lay down cannons of inquiry. But there is no technique for forming good hypotheses which can be taught. Discussions of scientific method are often trite, and seldom useful.—I. M. D. Little, *A Critique of Welfare Economics,* Introduction.

MUCH dissatisfaction with the orientation of agricultural economics research has been voiced in recent *Journal* articles.[1] Lack of adequate theories is a major source of the dissatisfaction. A more theoretical orientation of research in agricultural economics and more effort in building needed theories thereby seem implied. A sequence of articles by A. N. Halter, one in collaboration with H. H. Jack, implies that the source of our theoretical deficiencies lie in our philosophy (and method) of science and the remedy is to reorient our philosophy (and methodology).[2] These articles propose a philosophy and methodology for agricultural economists.

The major objective of this paper is to critically appraise this proposed philosophy and methodology as a remedy to our theoretical deficiencies. Accomplishment of this task requires some assessment of our theoretical problems and a summary of interpretation of the viewpoint proposed by Halter and Jack. Since any appraisal of a viewpoint reflects

* Journal Manuscript No. 708, Oklahoma Agricultural Experiment Station. Many of the ideas in this paper grew out of discussions on philosophy and methodology with my colleagues, E. J. R. Booth, Clark Edwards, L. V. Blakley, L. F. Miller, W. F. Williams, and J. S. Plaxico; however, I am responsible for the ideas as presented.

[1] Cf. Karl Brandt, "The Orientation of Agricultural Economics," *J. Farm Econ.*, Dec. 1955; James S. Plaxico and Fred H. Wiegmann, "Allocation of Resources in Farm Management and Production Economics Research," *J. Farm Econ.*, Feb. 1957; George K. Brinegar, Kenneth L. Bachman and Herman M. Southworth, "Reorientations in Research in Agricultural Economics," *J. Farm Econ.*, Aug. 1959. Another article expressing dissatisfaction with the orientation of agricultural economics research, but not necessarily from our efforts to develop theory, was by Kenneth L. Parsons, "Logical Foundations of Economic Research," *J. Farm Econ.*, Nov. 1949.

[2] A. N. Halter, "A Metaphysical Hypothesis," *J. Farm Econ.*, Dec. 1958; A. N. Halter, "The Identification of Problems in Agricultural Economics Research," *J. Farm Econ.*, Dec. 1960; and A. N. Halter and H. H. Jack, "Toward a Philosophy of Science for Agricultural Economic Research," *J. Farm Econ.*, Feb. 1961.

a viewpoint, I shall endeavor to make explicit some of the philosophical considerations underlying my appraisal.

A Brief Assessment of Our Theoretical Problems

Dissatisfaction with the theoretical status of economics and of agricultural economics has been expressed as follows:

> . . . the time has come where our science must mature toward the development of theory . . . a theory . . . of the economic order as it evolves within the boundaries of the political constitution and social philosophy of a country.[3]

> . . . if our research is limited to the estimation of presently known models or relationships, we will do little more than scratch the surface of real problems. Research is also needed to develop theory.[4]

> Lack of an adequate theory of growth or economic development is the most obvious need of agricultural economists or of economists generally. The direct quest of such a theory does not appear promising, since no science has adequate understanding of cumulative change. Many of the relevant questions must therefore be cut from a finer canvas than that of a general theory.[5]

These statements, and the accompanying discussion thereto, indicate our theoretical gaps to be in both statistics and dynamics, but mainly the latter.[6] The purposes of the recommended additional effort to develop theory range from a desire to explain more satisfactorily the operations of our economy to a desire for theory for use in analysis of economic problems of people. Irrespective of purpose, I believe our theoretical problem is the low explanatory and predictive power of what we generally conceive to be our theory.[7]

What we conceive to be our theory was not derived by agricultural

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[3] Karl Brandt, *op. cit.*, p. 804.

[4] Plaxico and Wiegmann, *op. cit.*, p. 87.

[5] Brinegar *et al.*, *op. cit.*, pp. 606-7.

[6] A similar view of our theoretical needs was voiced by Glenn L. Johnson about a decade ago. See his "Needed Developments in Economic Theory as Applied to Farm Management," *J. Farm Econ.*, Nov. 1950.

[7] I refer specifically to micro-static economic theory. Achievement of rigor and logical consistency is a necessary goal in theory construction, as is the achievement of greater explanatory and predictive power of economics. Some would view our theoretical problem as a lack of realism of present theories. In criticizing efforts to obtain a greater degree of realism in theory, Milton Friedman states: "The confusion between descriptive accuracy and analytical relevance has led not only to criticisms of economic theory on largely irrelevant grounds but also to misunderstanding of economic theory and misdirection of efforts to repair supposed defects. 'Ideal types' in the abstract model developed by economic theorists have been regarded as strictly descriptive categories intended to correspond directly and fully to entities in the real world independently of the purpose for which the model is being used. The obvious discrepancies have led to necessarily unsuccessful attempts to construct theories on the basis of categories intended to be fully descriptive."—*Essays in Positive Economics*, p. 34. Thus, I would be more reluctant than Halter and Jack in calling Friedman a subscriber to the "empiricist" view if their stated criterion for theory of "genuinely descriptive and explanatory" means "fully descriptive."

economists but by general economists. A major purpose in its development was to achieve rigor and logical consistency, and this purpose predominated over achieving explanatory and predictive power. Emphasis was placed on development of concepts and principles of a generic character, but the tendency has been strong to equate these with empirical relevance.[8] Whether this theory adequately serves the purposes of the general economists is not the question at hand; their purposes may differ from ours. Rather, the problem from our standpoint is that the theory we have is inadequate for predicting consequences of alternative changes in circumstances within the agricultural sector of the economy with the desired degree of accuracy.

I assume Halter and Jack would agree, at least in part, with my assessment of our theoretical problem. Apparently our major differences arise from other grounds, i.e., whether this theoretical problem arises from inadequacies of our philosophical viewpoints for developing theory and whether their proposed viewpoint is a remedy for this deficiency.[9]

A Summary and Interpretation of Halter's Viewpoint[10]

Two of the three papers in the series were claimed to be responses to Karl Brandt's recommendations to the profession in 1955.[11] In the first paper ("A Metaphysical Hypothesis"), a semblance of a viewpoint could be detected from the following concluding sentences:

. . . a metaphysical study of agricultural economics (and in general social sci-

[8] For example, Robbins and Knight, as discussed by Halter and Jack (*op. cit.*, pp. 87 ff.).

[9] In the introduction to their article, Halter and Jack state: ". . . a philosophical analysis of the issues involved provides an orderly way of reviewing the controversies and confusion surrounding discussions of economic theory. Such an analysis would seem to be a necessary, if not a sufficient condition of progress in this area. Accordingly in this paper . . ." (*op. cit.*, p. 84). Also, in the conclusions to the paper, they state *imperative* conclusions regarding our activities in developing theory which, logically, require their philosophical viewpoint as the crucial premise. However, one may agree with the conclusions as stated on the bases of other philosophical viewpoints. Thus, I conclude their viewpoint is not a necessary condition for progress in developing theory. Later, I question its sufficiency for this purpose.

[10] I assume that the viewpoint of H. H. Jack, co-author of one of the articles, is the same as that of Halter.

[11] A footnote to Halter's "A Metaphysical Hypothesis" (*op. cit.*, p. 1871) states: "In 1955, Karl Brandt pointed out to the American Farm Economic Association meeting that a study of philosophy would lend clarity to our understanding of the nature of economics and to its research methods. . ." What Karl Brandt actually said (*op. cit.*, p. 806) was as follows: "If it should be a sound endeavor to orient economics more toward theory, I doubt that concentration on methodology will help . . . more exchange of thought with general economists, and *discourses on problems of economic development* with researchers in other disciplines such as philosophy, logic, philosophy of law, jurisprudence, political science, economic history, and anthropology will not only widen horizons but give by analogy or transposition a firmer grasp of what economics is and what it cannot be." (Italics mine.)

ence) would result in uncovering of some methodological entanglements . . . A comparison with the physical sciences would show the inefficiency of present presuppositions and the absence of others, probably more efficient, in the social sciences.[12]

The term "metaphysics" as used by Halter means "the discipline which concerns itself with the presuppositions underlying science."[13] From various statements by Halter, I interpret a "metaphysical study" to mean some philosophical analysis or study—a study within philosophy, not science.[14] Thus, I interpret the statement quoted above to mean that a philosophical study would reveal the need for changing our conception of science and of scientific method to that which philosophers interpret to be the viewpoint of physical scientists. Why this "divinity" of physical science? By what criteria can philosophers choose from among alternative sets of metaphysical presuppositions? The subsequent articles in the series shed little (if any) light upon these questions. Instead, I interpret the content of these articles to be a presentation of the implications of a particular metaphysical viewpoint within physical science and a critical appraisal of agricultural economics therefrom.[15]

Halter and Jack call their viewpoint an empiricist view, but I prefer to call it a form of logical positivism.[16] Logical positivism, which stresses

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[12] *Op. cit.*, p. 1874. On the same page, there appears an apparent contradiction to the above quotation. It is a statement as follows: "Since a metaphysical study can only show what presuppositions are used or not used, it cannot predict that the adoption of certain presuppositions in social science will be more productive of results than those that are now used . . . Those that will be productive of results and adopted by social science can only be found by trying them out." I could fully agree with this statement if it admitted the proposition that metaphysical studies can also produce new presuppositions (as well as state what are used or not used). I submit, however, that had Halter taken seriously the statement as quoted in this footnote, the two subsequent articles would have been very different in content. For example, his conclusion that the depicted viewpoint of the subcommittee would result "in an unproductive pursuit" contradicts this statement of the limits of metaphysical studies. Cf. "The Identification of Problems . . . ," p. 1467.

[13] Part quoted is from "A Metaphysical Hypothesis," p. 1871.

[14] In "The Identification of Problems . . ." (p. 1470), Halter states: "That the methods of science cannot be applied to judging the results of science and technology is explicit . . . However, that some other method can evaluate the results is the intent of the presupposing relations . . . The examination of these metaphysical relations is the function of philosophy." The possibility of scientists also being philosophers is not excluded by this statement.

[15] If the articles in reference are "philosophical analyses," then I am unable to distinguish this type of mental discourse from "preaching," where the presuppositions of a viewpoint are taken to be ought propositions and used as premises for imperative conclusions. Perhaps in philosophy this goes under the name of "dogmatism," but it is a form of rationalization.

[16] I believe the term "empiricist" can be misleading. Many members of the profession would claim to be empiricists, but would claim to be adherents to Dewey's philosophy or subscribers to the inductive method proposed by Bacon. In "The Identification of Problems . . ." (p. 1469), Halter presented the view that the method of science was completely deductive.

the meaning and analysis of statements, places much emphasis, philosophically, on what goes under the name of semantics. In respect to science, it recognizes two kinds of meaningful assertions, analytic and synthetic, with the first having only validity content (definitional) and the second having empirical truth content. In the extreme form, it stresses the importance of talking only about observables in any scientific discussion.[17]

Whatever the viewpoint is called, it is a mechanical philosophy with at least one of the important metaphysical presuppositions being a deterministic view of the world.[18] This "Proposed Point of View" for agricultural economists, I believe, classifies what "ought to be" the activities of agricultural economists as scientific, technological, and influential (teaching, preaching and "politicking").[19] Our scientific activities, according to the view, should consist of "(1) proposing hypotheses, (2) deducing predictions, (3) attempting to refute the theory by 'risking' a comparison between prediction and observable facts."[20] Our technological activities

[17] Parts of the above paragraph are paraphrased statements from Anatol Rapoport, *Operational Philosophy* (Harper, 1954), pp. 194 and 235.

[18] This presupposition may aptly be described by the third meaning of "cause" identified by Halter: ". . . (1) if the cause exists, then the effect must happen; (2) if the effect exists, then the cause happened prior to the discovery of the effect. This is the theoretical use of cause and refers to events that happen independently of human action" ("A Metaphysical Hypothesis," p. 1872). An interpretation of this presupposition as quoted is that a theoretical explanation of economic conditions at t_0 is sufficient for predicting economic conditions at some future date (t_1). I doubt that agricultural economists can accept this as a necessary or sufficient viewpoint for constructing a theory of economic dynamics. The apparent success of this presupposition in physical science is partly due to the fact that physical scientists do not seek knowledge of cumulative change. For example, what the feed-gain ratio will be for choice steers by 1970 is a meaningless question to an animal nutritionist.

[19] Cf. "The Identification of Problems . . . ," pp. 1461-2 and 1467-9. Halter does not say explicitly that agricultural economists could carry on activities said to be the function of philosophy. However, statements he and Jack made suggest that philosophy has authority over science, particularly social science, and we have little choice but to "submit." For example, in disagreeing with Robbins and Knight regarding the postulates of economics, but agreeing with Hutchinson, they state: ". . . it must be noted that appeals to 'intuition,' 'obviousness,' 'self-evidence,' etc., have long since been discredited in mathematics and the natural sciences. This has led most modern philosophers of science to espouse empiricism and to maintain that all knowledge of fact must be based on observation . . . Since modern philosophical analysis has made it clear that 'intuitionistic' doctrines of necessary knowledge of reality essentially involve the doctrine of valid a priori synthetic statements, most philosophers of science now reject the view that there can be a priori synthetic knowledge, at least in science. We feel, therefore, that the weight of opinion requires proponents of a priori synthetic statements in economic theory to assume the onus of proof for their position." ("Toward a Philosophy of Science . . . ," p. 89.) I believe Halter and Jack are misleading in giving us that impression that philosophers of science are near unanimous in agreement with their viewpoint. Nowhere in their paper do I find references to Dewey, Northrop, Bridgeman, Cohen, Nagel, Lewis, Miller, and numerous others who have made major contributions to philosophy of science.

[20] Part quoted from "The Identification of Problems . . . ," p. 1469. Additional parts

should consist of taking whatever is available of social, physical and normative (value) theory for the purpose of developing technical and institutional instruments of practical worth. According to the view, the scientific method is inappropriate in technological activity. Our influential activities (teaching, etc.) are identified as deliberate efforts to influence social facts (behavior) by use of the available technical and institutional instruments. Also, according to the view, these must occur in the order listed, i.e.., science must precede technology and technology must precede teaching or other influential activities.[21]

The implications of the proposed classification may be made sharper by relating it to actual activities of agricultural economists. Some agricultural economists may describe their research activities about as follows: (1) determine or ascertain "real-world" problems, (2) through a joint use of theory and available facts, develop tentative explanations of problems (hypotheses), (3) design samples or experiments for generating data appropriate for estimation or testing hypotheses, (4) from analyses of data (estimation, etc.), choose from among alternative explanations of problems, and (5) estimate consequences of alternatives in action to alleviate these "real-world" problems. Are these activities scientific? According to the above definition, I believe Halter would say no because (1) the purposes are not restricted to developing and testing theory, and (2) the procedure differs from *the* method of science. Are they technological? No, because (1) the purposes are not restricted to developing technical or institutional instruments of practical worth from existing theory, and (2) the method is not limited to a "digestion" of what already is known. Perhaps the "empiricists" would call these activities a hopeless confusion of scientific and technological activities, combined with the "myth" of induction, and would argue agricultural economists adhering to such practices need a "philosophical education." Halter and Jack are courageous indeed in giving us a "philosophical analysis" for a guideline. Their proposal appears to amount to our dropping what we now are doing, learning what science and scientific method are all about (as presented, of course, by the "empiricist" philosophers), and then making a new start to build a science of agricultural economics.

The last article in the series, "Toward a Philosophy of Science . . . ,"

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to the statement are as follows: "This is the program proposed by the empiricists to set scientific endeavors apart from technological. Thus, induction, i.e., inference based on many observations, according to K. R. Popper, is a myth."

[21] I get this interpretation from the arrows of the diagram depicting the "Proposed Point of View," ("The Identification of Problems . . . ," p. 1468) and from the following statement by Halter and Jack in their conclusions: "Then, and only then [after we have obtained an empirical explanation of farmers' behavior], can we see that the farm economist can take the role of teacher, engineer or moralist." ("Toward a Philosophy of Science . . . ," p. 95.)

presents some details on how we can construct theory and, thereby, a science of agricultural economics. The emphasis is on the characteristics of statements in a theory (semantics), descriptive and explanatory characteristics of theory, and testability. The comparison of their criteria with two examples applies mainly to the criterion of testability (predictability).

The statements of a theory are reduced to two kinds: a priori analytic, or definitional; and a posteriori synthetic, or statements for which verification through experience is necessary for knowing their truth value. A priori synthetic statements, such as the postulates of economics, are eliminated because "intuition" is inadmissable within their viewpoint.[22] In constructing theory, deductions of a posteriori synthetic statements having the characteristics of being "genuinely descriptive and explanatory" and of testability (predictability) are to be made from a posteriori laws. Halter and Jack fail to provide us with instructions on what to do if we have no a posteriori synthetic laws.

Our usual ideas on what constitutes verification of theory would need overhauling according to the proposal. By the proposal, theory (hypothesis) is verified by comparison of predictions therefrom with actual events irrespective of human action, not by application of statistical inference nor by observation of consequences of action. Halter and Jack are not clear just what role, if any, can be assigned to statistical inference in research. If the social world were static (or stationary) and we could observe, without error, all relevant events, then we could dispense with statistical inference.

An Evaluation of the Proposal

About a decade ago, there appeared in our *Journal* another "philosophical analysis" with accompanying prescriptions for agricultural economics research, an analysis from the philosophical viewpoint of John Dewey. However, that analysis resulted in a different set of conclusions

[22] I was surprised to find that Halter and Jack omitted a discussion of Milton Friedman, whom they consider to be an "empiricist," in their discussion of a priori synthetic statements in economic theory. Friedman did not reject a role for intuition in research. For example, in his *Essays in Positive Economics*, p. 26, he states: "The particular 'assumptions' termed 'crucial' are selected on grounds of their convenience in some such respects as simplicity or economy in describing the model, *intuitive* plausibility, or capacity to suggest . . ." (italics mine). (See also p. 43 of this essay.) Shall we throw away an intuitive proposition if it enables us to make a successful prediction, simply because it is intuitive? Have not economists made some important contributions to the science through application of intuition? I interpret Friedman's message to be that the empirical truth value of the assumptions of a theory does not matter—usually they are false; what matters is that they yield testable (although not "truistic") predictions. The assumptions of a theory *are* statements of some kind; are they synthetic a priori? That is, are they treated a priori *as if* they were true, regardless of whether or not they are, in fact, true?

than those by Halter and Jack.[23] Actually, there are many varieties (and strains within varieties) of philosophies of science. Many of these are represented among the population of agricultural economists. One could make a "philosophical analysis" of our subject by any one of these viewpoints, and a different result would be forthcoming from each analysis. In such a situation, by what criteria shall we choose our philosophy of science? My personal viewpoint is that no particular philosophy (or methodology) is sufficient for handling all problems of agricultural economics and that our methods should depend upon our problems. This is an eclectic viewpoint of methodology.

An eclectic viewpoint with emphasis on the "primacy of the problem and the attendant relativity of scientific methods" is the antithesis of the practice of permitting a particular conception of methodology, or of the available techniques, to determine the problems for agricultural economics research.[24] Much of agricultural economics research may be "technique oriented," but, if so, what Halter and Jack propose is not a remedy. It would replace dominance of currently known techniques with dominance of a particular philosophy of science and accompanying methods.

The status of agricultural economics provides some support for an eclectic philosophy. For some of our problems, we have no theoretical guidance at all, or very little idea of what is relevant in needed theory. In this situation, the proposal by Halter and Jack is of no help.[25] For some of our problems, the theory we have "fits" sufficiently well for us to use it, but there are alternative methodological viewpoints to that offered by Halter and Jack for proceeding with the expansion of such theory. For example, I believe Koopmans expresses a viewpoint and methodology worthy of consideration for this type of effort:

> . . . it is desirable that we arrange and record our logical deductions in such a manner that any particular conclusion or observationally refutable implication can be traced to the postulates on which it rests . . . considerations of this order suggest that we look upon economic theory as a sequence of conceptual *models* that seek to express in simplified form different aspects of an always more complicated reality . . . It is by adopting this concept of economic theory that we can resolve the apparent conflict between rigor and realism . . . realism will always be ahead of rigor in the gradual extension of the range of

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[23] Kenneth L. Parsons, *op. cit.*

[24] Quoted portion is from F. S. C. Northrop, *The Logic of the Sciences and the Humanities*, p. ix.

[25] Northrop calls the pre-theoretical stage of a science the natural history stage. He states: ". . . if one proceeds immediately to the deductively formulated type of scientific theory which is appropriate to the third stage of inquiry, before one has passed through the natural history type of science . . . , the result inevitably is immature, half-baked, dogmatic and for the most part worthless theory." *Ibid.*, pp. 37-8.

economic knowledge. But unless rigor follows along to consolidate the gains in realism, we shall not know which conclusions or recommendations depend on which postulates, and which postulates depend for their validity on which verifications of their implications by accumulated experience.[26]

Acceptance of this viewpoint by Koopmans does not require a devotion to semantics. Much of our research is of this nature, although perhaps less "formal" than suggested by Koopmans. I am not, of course, ruling out completely the proposal by Halter and Jack. I am just trying to put it in proper perspective. For those situations where much theory already has been constructed and the problem is amenable to a mechanical solution, some of the methods they propose may be fruitful.[27] However, I am not in favor of restricting agricultural economics to problems which the proposed methodology may possibly be adequate for solving.

I am not convinced it is possible, or even desirable, to separate science and technology within agricultural economics in accordance with Halter's definitions. As scientists, by the proposed definition and description of activities, we would be sterile, and the public providing our financial support likely would render the mortal blow. As strictly technologists, we would be continuously in want of social and physical theory relevant for the problems at hand, and we would be in a quandary about a choice from many normative (value) theories with perhaps none really relevant to the problem. For example, many of the "ethical" problems we encounter as economists relate to income distribution. What normative theory exists which provides a defensible answer to the question of how income should be distributed? Economists long have searched without success for an answer to this question. The suggestion by Halter and Jack that we must have an explanation of farmers' behavior before we can be moralists is naive. This seems to suggest we can substitute a subject without moral content for one with such content. I suspect the program of the "empiricists" to separate scientific from technological activities may work reasonably well for physical science. But contrary to physical science, success of "engineering" in social science is not automatic with development of social theory.

I do not believe the proposed criteria for a theory really touch the problem of the limited predictive power of economics. I shall demon-

[26] Tjalling C. Koopmans, *Three Essays on the State of Economic Science*, pp. 142-3.

[27] One consequence of the deterministic presupposition in their viewpoint is the exclusion of human values from the content of social theory. I already have elaborated on this point (see my Discussion of "The Identification of Problems . . . ," *J. Farm Econ.*, Dec. 1960, pp. 1471-4). Halter does not appear to take this presupposition seriously; his research with Beringer was an effort to provide knowledge of values of farm managers (see "Cardinal Utility Functions and Managerial Behavior," *J. Farm Econ.*, Feb. 1960). The limitations of a mechanical philosophy for dealing with human values are expressed well by Gunnar Myrdal, *An American Dilemma*, pp. 1032-4.

strate by use of the example said to be in accord with these criteria. This example was the work by Wold in deriving estimates of parameters of demand for milk in Sweden. These estimates were transformed into predictions of milk consumption in that country under price controls for a decade following the initial study. The prediction had about a 19 percent error (or, alternatively, it was 81 percent accurate—paging Drew Pearson!). Suppose the error had been 50 percent; then what?[28] Would we reject the theory of demand that provides the conceptual guidance to development of the parameter estimates, the parameter estimates themselves, or both? Or, would we simply conclude that conditions necessary for a fair test were not present after all? Halter and Jack provide no definite criteria for deciding what constitutes sufficient accuracy in prediction to warrant accepting (or rejecting) a hypothesis. Instead, they refer to Friedman on this point.[29] I suggest we could provide parameters and word most of our present theories to make them appear genuinely descriptive, explanatory and predictive. But, having done so, what have we accomplished? We know in advance our theories are static (or comparatively so), whereas we need dynamics to achieve the theoretical status of a mature science envisioned by Karl Brandt. Just behavioristic "predictions" is hardly an answer to our problem.[30]

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[28] Numerous exogenous conditions could have created such size of error, including change in preferences of consumers for milk and/or competing products, changes in quantities (and prices) of products competing with milk, etc.

[29] If my interpretation of Friedman is correct, he would accept any hypothesis so long as (1) its predictions are sufficiently accurate to serve the purposes of the scientist (whatever those may be), (2) no alternative hypothesis is available that will yield more accurate predictions, and/or (3) the hypothesis fits a criterion of "analytical relevance" (as opposed to descriptive realism). Friedman admits outright that this is a matter of judgment, and, in referring to use of judgment for deciding what aspects of a model are relevant for comparisons with observables, he states that a fine line separates the "crackpot" from the scientist. This is hardly a useful answer to the question of what criteria to use in accepting or rejecting a hypothesis. I get the impression the criteria presented are as indefensible as testing the hypothesis by the realism of its assumptions, which Friedman made a great effort to reject. Would not statistical inference be superior to judgment or intuition for evaluating predictions?

[30] The second example by Halter and Jack, one they criticize as inconsistent with criteria of a scientific theory, is the work of Heady in deriving parameters of production functions ("Toward a Philosophy of Science . . . ," pp. 94-5). His work was carried out cooperatively with the physical scientists of Iowa State University over a period of years. The derived parameter estimates applied strictly to the physical production functions. Heady uses the term "prediction" in relation to these estimates as physical scientists use this term. I believe Halter and Jack may have placed a "convenient" rather than an "accurate" interpretation upon Heady's work. Their discussion of this work seemingly contained the presupposition that all models and hypotheses in production economics must be predictive and behavioristic. I object to the use of "philosophy" for prescribing the content of a subject such as production economics. Only production economists can do that. Particular kinds of physical relations, those that physical scientists have not made it a practice to estimate, are basic ingredients of contemporary production economics. Realistic behavioristic models are not prerequisite

I am not willing to rely solely on some vague degree of agreement between predictions and observable events as a criterion for verifying theory. The experiments that just happen to turn up to test our theories may occur so infrequently that we shall forever be relegated to the ivory towers of rationalism, no matter how good our intentions to be "empiricists." I fail to see any convincing reason for tossing out statistical inference as a part of our testing procedure. Also, the "usefulness" of theory for analyzing "real world" problems and for estimating consequences of alternatives in action is an important test of the theory. We discriminate among theories on the basis of how well they measure up in application to expectations. This test exposes any intolerable lack of realism associated with theory, and it is partly through these sorts of experiences that we derive our judgments about the status of our theory. I would venture a hypothesis that confidence in physical theories has been strengthened more by results in application than by any casual observation of conformity of predictions with events in the physical world.

Concluding Remarks

I believe it is necessary for us to give continuous thought to our methodology, but is there not a better alternative to writing and publishing "sermons" on the subject? I believe so. One such possibility is our being more explicit in stating our methodology in reporting successful research efforts to our colleagues, particularly when new methods have been found to be successful. As a prerequisite to this, we do need to try different methods in our research, even though they may be based upon differing philosophical viewpoints. I believe the Social Science Research Council Committee on Agricultural Economics made a plea for trial of new methods.[81] I have suggested in this paper the possibility that none of the particular philosophies of science currently in existence is sufficient as a philosophical guide to research on all the problems of agricultural economics, but many may contain elements that are useful for advance of the science, including the proposal by Halter and Jack.

It is difficult to state recommendations that would add to those by Karl Brandt and by the subcommittee of the Social Science Research Council. However, I will add a footnote to the subcommittee's recommendations. Although I can agree that agricultural economics is compartmentalized by methodologies and subject matter, and therefore may be making meager progress toward the development of theory, I have limited facts to substantiate this belief. The subcommittee's recommenda-

to usefulness of the physical production functions to farmers, although the lack of these models may be considered a major theoretical gap in production economics, e.g., for purposes of policy evaluations.

[81] Brinegar *et al.*, "Reorientations in Research in Agricultural Economics," *op. cit.*

tion of a "study of agricultural economics by agricultural economists," I believe, could be more specific. I suggest an organized study by one or a few agricultural economists, adequately financed, and with the purpose of creating a monograph which documents factually the relevant characteristics of agricultural economics research.

EDITOR'S NOTE: Messrs. Halter and Jack plan to offer a reply to Mr. Back's paper for publication in a subsequent issue.

ECONOMIC ANALYSES INVOLVING RANDOM WEATHER INPUTS*

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WEATHER has an important effect upon the profits of a farm business. Agricultural economists have long tempered the results of their research with assumptions concerning weather conditions. In more recent years, some research has dealt directly with problems of soil moisture, droughts or rainfall, and year-to-year variations in yield.[1] As yet, however, a completely adequate method of analyzing random inputs has not been formally incorporated into the economic logic governing resource use within individual firms.

The purpose of this article is to present an empirical application of a method of analysis that can be used to determine resource use when a random weather input affects the production process. Also included is a discussion of the effects of random inputs upon the validity of conventional procedures for maximizing profits from inputs under the control of the manager.

Theoretical Discussion

Some of the inputs used in an agricultural production process may be controlled in amount by the manager. Other inputs, such as weather inputs, may be random in nature.[2] Consider an agricultural production

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[1] A bibliography of recent research conducted by economists and meteorologists can be found in James D. McQuigg and John P. Doll, "Weather Variability and Economic Analysis," Mo. Agr. Expt. Sta. Res. Bul. (in press).

[2] We assume that weather variables are random rather than cyclical in nature. While day-to-day weather is undoubtedly correlated, many meteorologists believe that climatological series are random. See D. G. Friedman, "The Prediction of Long-Continuing Drought in South and Southwest Texas," The Travelers Weather Research Center Occasional Papers in Meteorology, No. 1, Sept. 1957; H. C. S. Thom, "Climatological Series" in *Three Chapters on Climatological Analysis*, unpub. ms. of the U.S. Weather Bureau, Aug. 1960.

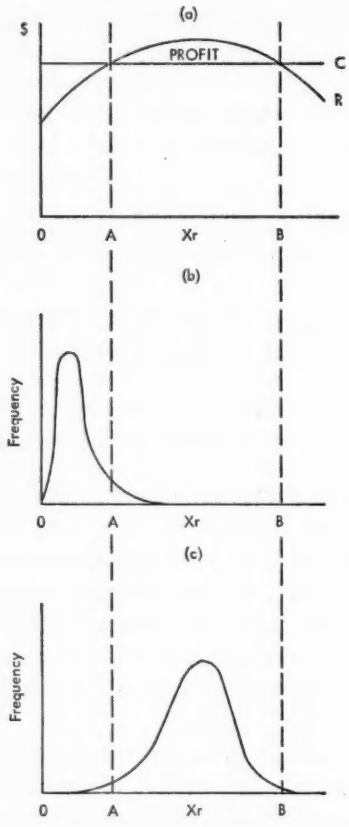

FIGURE 1. HYPOTHETICAL COST AND REVENUE FUNCTIONS PRESENTED WITH TWO PROBABILITY DISTRIBUTIONS FOR A RANDOM WEATHER INPUT, X_r.

process involving two variable inputs, one a controlled input and one a random weather input. If the inputs do not interact, the marginal physical product of each input is independent of the other input. In this case, given the appropriate stability conditions, the most profitable or optimum amount of the controlled input can be determined by the usual marginal criterion. This optimum will be invariant to the magnitude of the random input and the manager can rationally apply the marginal conditions of resource allocation to the controlled input.

When the controlled input is held constant at its optimum amount, output may be expressed as a function of the random input only. Functions depicting the effects of the random weather inputs upon costs and returns may be derived. Examples of such cost and return functions are given in Figure 1a, where X_r is the random input. Functions differing in form from the ones presented are possible, depending upon the effects of the random input in the particular situation being investigated.

Profit, P, is equal to returns minus costs. In Figure 1a, A and B represent amounts of the random input within which a positive profit is made; they are profit limits or break-even points. If a minimum allowable profit were desired, perhaps because of an opportunity cost, the limits could be shortened.

A manager has two types of meteorological knowledge to use with the cost and returns analysis in Figure 1a. These are weather forecasts and historical climatological data. A weather forecast can be categorical, stating that the random weather input will have a definite value. If the forecast is accurate, the analysis in Figure 1a will reveal the effects upon profits. However, managerial decisions must often be made weeks or months in advance. When the time interval between the time of decision and the occurrence of the event is beyond the capabilities of the forecasts, such as when durable assets are being purchased, historical climatological data must be used.

Even if cost and revenue functions are known in the last-mentioned situation, the manager would still not know the expected level of profit. To determine expected profit, the probability distribution of the random weather input must be known. While the true population distribution will never be known in practice, it can often be estimated from historical climatological records. Therefore, if cost and revenue functions for X_r are known as in Figure 1a and X_r is distributed as in Figure 1b, the manager could expect a loss almost 100 per cent of the time, for almost 100 per cent of the values of X_r fall outside the limits of A and B. If X_r were distributed as in Figure 1c, the manager would expect a profit almost 100 per cent of the time. Thus, the area of the probability distribution occurring between A and B is extremely important. In most practical situations, the relationship of the probability distribution to the cost and revenue curves for random input variables undoubtedly falls between the two extremes presented in Figure 1. It is worth noting, however, that very little of the research in agricultural technology has been devoted to determining either the limits of profitability for an enterprise or the probability of the random input occurring within these limits. Usually, farmers or applied farm management men have had to determine such facts for themselves.

When revenue and cost functions, along with the probability distribution, for X_r are known, the expected profit, $E(P)$, resulting from the production process can be computed using usual methods of computing mathematical expectations. If $E(P) > K$, where K is the opportunity cost mentioned above and may be zero, then the production process would be profitable over time. When several alternative technologies result in $E(P) > K$, the most profitable alternative or, as discussed later, the alternative most compatible with the manager's goal will be selected.

When $E(P) \leq K$, the production process is unprofitable over time. In this situation, the manager may adopt different production practices. The most readily apparent solution would be the adoption of practices that would increase the profit area by shifting or changing the shape of the revenue and cost functions; this might involve adopting new technology to increase production, decrease costs, increase production more than costs, etc. The purpose of these changes would be to increase the probability of making a profit or to increase the magnitude of profits when earned. In the latter case, notice that $E(P)$ could be increased even while the area of the probability distribution between A and B—the probability of making any profit—is reduced. Another technological change would involve a shift in the timing of the operation to take advantage of different climatological probabilities. Or, the manager might abandon the procedure involving X_r and substitute another input; thus, a farmer in a low rainfall area may decide to purchase irrigation equipment. As an alternative to a change in technology, the manager may decide to completely abandon the enterprise.

When the controlled and random inputs involved in the production process interact, the marginal physical product of each input is dependent upon the magnitude of the other input. In this case, the optimum amount of the controlled input cannot be determined by the usual marginal criterion; it will vary depending upon the magnitude of the random input. The manager is faced with the dilemma of using a small amount of the controlled input and foregoing a profit some years or of using a large amount and incurring a loss some years. This problem can be solved by determining the profit limits, A and B, for the random variable, computing $E(P)$ for each relevant magnitude of the controlled input, and selecting the amount of the controlled input that comes closest to attaining the manager's goal.

When controlled and random inputs interact, "profit maximization" in the traditional sense loses relevance. The "profit maximizing" amount of the controlled input becomes that amount that maximizes expected profits.

From the above discussion, it would appear that the manager is faced with any number of rational decisions when dealing with random weather inputs. He may act to maximize expected profits, to maximize the probability of making a profit, to minimize the probability of a total loss, etc. These may not always be mutually exclusive goals. In the short run, the manager possessing limited capital may prefer to select a goal other than long run profit maximization if he can thereby increase the probability that enough profit will be earned each year to meet annual expenses and insure the short run survival of the firm and the family. In the long run, these latter goals would appear to be most readily accomplished by maximizing $E(P)$.

Practical interpretations of cost and revenue models for random inputs, such as presented in Figure 1a, are numerous. For example, managerial actions that lower costs or increase revenue can also increase expected profits and the probability of a profit. Poor managers would be characterized by lower revenue functions, higher cost functions, and smaller profit zones than good managers. Thus, the poor manager not only earns a smaller profit than the good manager but he also earns it less often, i.e., reduces the probability of a profit. The outcome of the analysis depends upon the forms of the relevant functions, of course.[3]

An Empirical Application

Weather conditions are closely related to the drying of corn, whether in a field or in a grain drying bin. Thus, the model presented above will be used to determine the number of natural air grain drying bins that should be purchased for a Central Missouri farm. A partial budgeting approach will be used; only costs and returns added by the grain drying equipment will be considered.

Profits from grain drying are affected by the weather in two ways. First, weather conditions during the growing season affect corn yields and the number of grain drying bins needed. For the following analysis, a frequency distribution of corn yields for Central Missouri has been estimated using 21 years' data from a fertilized continuous corn plot on an experimental field. Second, weather conditions after harvest determine the length of time required by the natural air drying process. A mathematical model, based on physical and engineering concepts, has been developed to enable computation of the amount of drying accomplished by forcing air through a grain bin.[4] Temperature and moisture content of the air and the moisture content of the grain, determinants of the rate of grain drying, are taken into consideration by the model.

It is assumed that the farm has 120 acres of cornland and yields per acre vary from 0 to 100 bushels per acre, computed just before harvest while the corn is standing in the field at 25 per cent moisture. Each grain drying bin holds 2000 bushels of shelled corn. Drying is accomplished by forcing unheated air into a plenum chamber, through a false floor, and up through the grain.

To simplify the analysis for presentation, only two alternatives will be

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[3] The problem discussed in this section can be presented in a game theory context by regarding the manager, selecting the controlled input, as the maximizing player and the weather, controlling the random input, as the minimizing player. Game theory solutions may sometimes be applicable to weather problems, depending upon the accuracy and precision with which the relevant probability distributions can be estimated. See T. A. Gleeson, "A Prediction and Decision Method for Applied Meteorology and Climatology, Based Partly on the Theory of Games," Sci. Rept. No. 1, Dept. of Meteorology, Fla. State Univ., June 1959.

[4] D. B. Brooker and J. D. McQuigg, "Analysis of Weather Data Pertinent to Grain Drying," *Trans. Amer. Soc. Agr. Engineers*, Vol. 3, No. 2, pp. 116-9, 1960.

discussed here. Clearly, many more are available to a farm manager. The two alternatives are:

1. Corn is harvested with a picker-sheller at 25 per cent moisture content, with field loss estimated at 10 per cent. The shelled corn is dried to 14 per cent moisture content by means of natural air drying equipment and placed in government storage at a price of $1.14 per bushel.

2. The corn is left in the field to dry down to 17 per cent moisture content. It is harvested with a picker-sheller, with 15 per cent field loss, and sold immediately with dockage to 15.5 per cent moisture. The market price received in this alternative will be left as a variable.

The cost of owning and operating natural air grain drying equipment, C, is

$$C = \$125.00\, N_1 + \$3.65\, N_2\, n \tag{1}$$

where N_1 is the number of bins owned, N_2 is the number of bins operated, and n is the number of days drying time. The annual fixed cost of owning a bin and drying unit is $125 and the daily cost of operation is $3.65.[5]

Total revenue from the use of drying equipment is equal to the bushels of corn available after the drying process is completed multiplied by the loan price per bushel of corn. When the total amount of corn grown exceeds the drying capacity of the bins owned, the excess corn is assumed to be left in the field and harvested and marketed as in alternative 2. Total revenue from alternative 1, R_1, is

$$R_1 = 1.14(1744)N_2 + P_2(0.754)(Y_0 - 2222N_2) \tag{2}$$

where Y_0 is the bushels of corn in the field at 25 per cent moisture and P_2 is the price per bushel of corn on the open market at harvest time.

Total revenue from alternative 2 is equal to the price per bushel of corn at harvest time multiplied by the number of bushels of field dried corn. Total revenue from alternative 2, R_2, is

$$R_2 = P_2(0.754)\, Y_0. \tag{3}$$

For the first alternative, 2,222 bushels of corn in the field will finally result in 1,744 bushels available for storage. For the second alternative, because of increased harvest losses and dockage, 2,222 bushels results in 1,675 bushels available for sale. Thus, under the assumptions of the analysis, each grain drying bin saves 69 bushels of corn. In addition to this saving, the grain drying alternative provides the manager with an opportunity to increase, through the use of a government loan, the price obtained for the 1,675 bushels available for sale in alternative 2. If grain drying is to be profitable, the value of the 69 bushels plus the increased returns on the

[5] Budgeting details underlying the cost and revenue equations are omitted for the sake of brevity. A complete development can be found in James D. McQuigg and John P. Doll, "Weather Variability and Economic Analysis," *op. cit.*

TABLE 1. OPEN MARKET CORN PRICES THAT MUST PREVAIL AT HARVEST TIME IF RETURNS FROM ALTERNATIVE 2 ARE TO EQUAL RETURNS FROM ALTERNATIVE 1

Number of bins used, N_2	Number of bins installed, N_1	Price when number of days required to dry bin load of grain from 25 to 14 percent moisture is—							
		6	8	10	12	14	16	18	20
		Dollars per bushel							
1	1	1.10	1.10	1.10	1.09	1.09	1.08	1.08	1.07
1	2	1.03	1.02	1.02	1.01	1.01	1.00	1.00	0.99
1	3	0.95	0.94	0.94	0.93	0.93	0.92	0.92	0.91
1	4	0.88	0.87	0.87	0.87	0.86	0.85	0.85	0.85
1	5	0.80	0.79	0.79	0.78	0.78	0.78	0.77	0.77
2	2	1.10	1.09	1.09	1.09	1.08	1.08	1.07	1.07
2	3	1.06	1.05	1.05	1.04	1.04	1.03	1.03	1.03
2	4	1.02	1.02	1.02	1.01	1.00	1.00	1.00	0.99
2	5	0.99	0.99	0.98	0.97	0.97	0.97	0.96	0.96
3	3	1.10	1.09	1.09	1.09	1.08	1.08	1.07	1.07
3	4	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.04
3	5	1.05	1.04	1.04	1.03	1.03	1.03	1.02	1.02
4	4	1.10	1.09	1.09	1.09	1.08	1.08	1.07	1.07
4	5	1.08	1.07	1.06	1.06	1.06	1.05	1.05	1.04
5	5	1.10	1.10	1.09	1.09	1.09	1.08	1.07	1.07

1,675 bushels must more than cover the costs of grain drying. If the corn price on the open market at harvest time is high enough, grain drying will not be profitable.

The break-even harvest price, that is, the price of corn that must prevail on the open market at harvest time if there is to be no advantage from the use of either alternative, can be determined by substituting the above numerical values into the expression

$$R_1 - C = R_2$$

and solving for P_2. Break-even prices for several combinations of N_1, N_2, and n, determined in the manner just described, are presented in Table 1. Thus, if a manager installs one grain drying bin, has a total yield that requires the operation of only one bin for six days and the price of corn turns out to be \$1.10 per bushel at harvest time, he will break even on his grain drying investment. If the market price is above \$1.10, he will lose money and if it is less than \$1.10, he will make a profit. If he installs five bins and only needs to operate one bin, the break-even price is only \$0.77 per bushel when 20 days drying time are required. The number of bins operated is dependent upon corn yields. As long as utilized capacity is equal to installed capacity, $N_1 = N_2$, the break-even harvest price remains constant. Unused capacity lowers the break-even price more than increases in drying time.

How much profit can be made by drying a bin load of grain? This question can be answered by referring to the distribution of the random

TABLE 2. FREQUENCY DISTRIBUTION OF TIME REQUIRED TO DRY A BIN LOAD OF CORN FROM 25 TO 14 PER CENT MOISTURE CONTENT BEGINNING ON SEPTEMBER 10, BASED ON 21 YEARS WEATHER RECORDS FOR COLUMBIA, MISSOURI

Required number of days, n	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Frequency (years)	1/21	1/21	2/21	1/21	1/21	4/21	1/21	1/21	4/21	1/21	2/21	—	—	1/21	—	1/21

weather parameter, the number of days drying time. A frequency distribution of the number of days required to dry a bin of corn from 25 to 14 per cent moisture, determined as mentioned earlier, is presented in Table 2. $E(n)$ for the natural air drying equipment is 11 days.

By using the frequency distribution in Table 2 and equations (1), (2), and (3), expected profits from drying one or more loads of grain can be computed. Table 3 includes expected profits for several combinations of bins installed, bins operated, and two levels of P_2, price per bushel of corn on the open market at harvest time. If one bin is installed and one bin is used, expected profit is \$180 when the market price of corn is \$0.98 per bushel. When two bins are installed and only one is used, expected profit for the same market price is \$55, \$180 minus the fixed cost of \$125. The probability of using one or more bins is not considered in Table 3; rather, the data represent profits to be expected if one bin is installed and used, two are installed and one is used, etc. The data again suggest the importance of fully utilizing grain drying equipment.

TABLE 3. EXPECTED DOLLARS OF PROFIT FROM DRYING ONE OR MORE BIN LOADS OF GRAIN USING NATURAL AIR EQUIPMENT, BASED ON 21 YEARS WEATHER RECORDS FOR SEPTEMBER, COLUMBIA, MISSOURI[a]

Number of bins installed, N_1	Profit when number of bins used, N_2, is—				
	1	2	3	4	5
			P_2=\$0.98		
			Dollars		
1	180				
2	55	359			
3	− 70	234	539		
4	−195	109	414	719	
5	−320	−16	289	594	899
			P_2=\$0.94		
1	247				
2	122	493			
3	− 3	368	740		
4	−128	243	615	987	
5	−253	118	490	862	1,234

[a] Based on a support price of \$1.14 per bushel of corn.

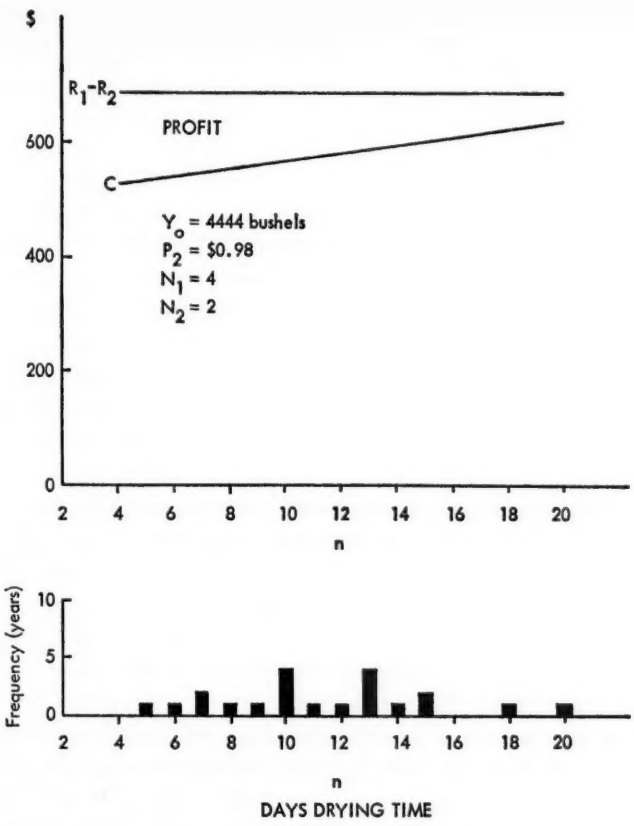

FIGURE 2. COST AND REVENUE AS FUNCTIONS OF THE NUMBER OF DAYS DRYING TIME, n, AND FREQUENCY OF OCCURRENCE OF n FROM 21 YEARS WEATHER RECORDS.

Cost and return functions for n, the number of days drying time, can be depicted graphically. When $Y_0 = 4{,}444$, $N_1 = 4$, $N_2 = 2$, and $P_2 = \$0.98$, the appropriate revenue and cost curves, along with a frequency distribution for n, are shown in Figure 2. The revenue function is actually $R_1 - R_2$, the increase in returns from grain drying. The cost function, C, represents the increase in costs due to grain drying. Profits decrease with drying time because costs increase and returns remain constant.

How many grain bins should be purchased per 120 acres of cornland? This question cannot be determined until the yield level and price of corn on the open market at harvest are known. When other inputs are held constant, yields are a function of weather conditions during the growing season and, assuming this latter weather "variable" is randomly distributed, the method of analysis presented above can be applied to yield variations caused by weather. The price of corn, however, is not a

TABLE 4. FREQUENCY DISTRIBUTION OF CORN YIELDS FOR COLUMBIA, MISSOURI[a]

Bushels per acre	Frequency
0.0–18.4	1/21
18.5–36.9	7/21
37.0–55.4	9/21
55.5–73.9	1/21
74.0–92.4	3/21

[a] Corn yields are from plot 18, continuous corn, on Sanborn Field of the Missouri Agricultural Experiment Station.

random variable in the sense discussed here. That is, a farm manager could undoubtedly obtain better price information by relying on current economic information, such as farm outlook or announced government price support levels, than by calculating a mean or expected price based on a distribution of past prices. Thus, the price of corn will be arbitrarily specified.

A frequency distribution of corn yields for Columbia, Missouri, is presented in Table 4. As mentioned earlier, these data were collected over a 21 year period from an experimental plot. In the absence of more refined measures of the effects of yearly weather conditions upon yield, the frequency distribution in Table 4 is used to approximate the distribution of Y_0. The class limits of the yields in Table 4 have been delimited to represent the required number of grain drying bins. If the yield on the 120 acres is less than 18.5 bushels per acre, no bins are needed. If the yield is between 18.5 and 34.9 bushels, one bin would be required and any excess would be left in the field and marketed as in alternative 2.

By making the not unrealistic assumption that weather conditions affecting yield are independent of those affecting drying time, the probabilities in Table 4 may be used along with profits computed as in Table 3 to determine expected profits for grain bins installed. Expected profits for two open market harvest price levels are presented in Table 5. When the market price is \$0.98 per bushel, two bins result in the highest expected profit for 120 acres of corn, \$229; when the price drops to \$0.94,

TABLE 5. EXPECTED PROFITS FROM THE INSTALLATION OF NATURAL AIR GRAIN DRYING EQUIPMENT BASED ON 21 YEARS' CORN YIELD RECORDS, COLUMBIA, MISSOURI[a]

Number of bins installed N_1	Profit if open market price of corn per bushel is—	
	\$0.98	\$0.94
1	\$165	\$229
2	229	334
3	162	280
4	80	208
5	−45	83

[a] Based on a support price of \$1.14 per bushel.

two bins still result in the highest profit, $334. The figures in Table 5 underestimate the profitability of grain drying bins because of the manner in which class limits for yields were established. That is, once a farmer purchased drying bins, he would be willing to dry partial loads. Such refinements can easily be included in the analysis.

Because of space limitations, no attempt will be made to compare expected profits and the probability of a profit for various combinations of purchased and utilized grain drying bins. In general, because the revenue and cost functions for the number of days drying time are linear, any change that increases (decreases) expected profit from this variable will also increase (decrease) the probability of a profit. For example, adding a fifth, unused drying bin to the analysis in Figure 2 would increase costs and decrease both expected profit and the probability of a profit. With respect to the weather variable affecting yields, the probability of a profit increases as the number of bins purchased decreases to one. Actual losses can be incurred regardless of yields, depending upon corn prices and the required number of days drying time.

The number of drying bins and the number of drying days do not interact. Profits are always largest or losses smallest when the number of drying bins purchased equals the number utilized, regardless of the length of the drying time. The weather "variable" affecting yields does interact with the number of drying bins; as yields increase, the number of bins required increases.

The foregoing is meant to be an applied example of the logic presented in the preceding section and is not a complete development of the grain drying problem. The analysis has been limited to two alternatives and the use of other alternatives, such as adding supplemental heat to the drying equipment, has not been discussed. The probability of completely or partially losing a crop left in the field because of unfavorable harvesting weather was not considered because adequate empirical information was not available. This latter consideration does sometimes occur in Central Missouri and would tend to make grain drying more profitable. Also, the use of grain drying equipment may affect farm profits in an indirect way. An early corn harvest facilitated by drying equipment might enable the farm manager to seed a small grain crop in the fall.

Conclusions

In order to analyse the effect of a random weather input on a production process, the input must first be identified and then a frequency distribution of the input must be derived from weather records. Fundamentally, this changes an uncertainty into a risk. By so doing, expected profit or the probability of a profit can be determined.

When random and controlled inputs utilized in the production process do not interact, the optimum amount of the controlled input is not affected by variations in the random input. When random and controlled inputs do interact, the optimum amount of the controlled input cannot be determined without first specifying or predicting an amount of the random input. Because of this, reference to an optimum amount of the controllable input seems to have little foundation when the inputs interact. Rather, it seems more reasonable to refer to an amount of the controlled input that maximizes expected profits, maximizes the probability of a profit, etc.

Historically, economists have assumed profit maximization as the goal of the farm manager. This assumption has often been tempered by the realistic knowledge that survival of the firm is also an important goal of the manager. When dealing with random inputs, these two goals may or may not conflict. Thus, the input combination that results in the highest profit may also result in the highest probability of a profit; in this case, the decision regarding input use is clear-cut. In the short run, when the two goals conflict the manager may rationally select either one. In the long run, maximization of expected profits seems to be the course most likely to insure the survival of the firm.

The analysis presented is preliminary—much remains to be done. The probability distribution for the random weather variables considered in this paper were based upon only 21 years data. No attempt was made to fit frequency distribution curves to the observed frequencies or to estimate the sampling error of the observed estimates. Needless to say, one of the main purposes of the work presented is to stimulate further thought and research on the economic implications of climatological events.

COMPUTER PITFALLS[1]

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WHEN large-scale, high-speed computation was introduced, the problem of handling vast quantities of data or performing complex operations was, in the minds of many individuals, finally solved. Even today the layman, having seen the computer in a Hollywood-type environment, pulling election results out of a handful of votes with barely a flick of the switch and quoting precise odds that dazzle even the

[1] Arizona Agricultural Experiment Station Technical Paper No. 652. This paper was originally presented in a Short Course on Computers and Computer Applications sponsored by the Department of Mining and Metallurgical Engineering and the Numerical Analysis Laboratory at the University of Arizona, April 4-7, 1961. The author is Professor of Mathematics and Agricultural Experiment Station Statistician.

nimblest of minds, regards all problems as trivial for any of the "brains" now on the market. Cost, preparation time, input-output relationships or any of a number of other problems confronting the numerical analyst today are seldom mentioned. It is not surprising, therefore, that the customer is somewhat taken aback when given an estimate of the costs of operating a computer or renting the services of a computer for handling what appears to be a routine problem. The additional costs of programming and analysis only add to the indignation when the total cost is announced. It is quite appropriate, therefore, that we spend some time on the ABC's of the pitfalls of the computer business. These need to be carefully spelled out for and thoroughly impressed upon the neophyte who feels he has found a panacea for his problems. Be assured, I am not trying to drive people away or even dissuade them from using a computer in their endeavors, but only to make sure they know the problems they will have to solve before they can appreciate the value of this new "arm" of research and production.

We should all clearly understand that any problem which can be solved on a computer can be resolved in the mind or evaluated by use of slide rule, desk calculator, or other mechanical means. The purpose of using the computer is either to reduce the time needed to attain some solution or to handle repetitive operations which are drudgery by slower methods. The methods by which our computers, which are scarcely more than high-speed adding machines, are instructed to handle problems are generally the same as we use in other methods of calculation, although some refinements have been made by the use of special facilities of the machine to cut down on the number of instructions that must be given to perform a specified task. The biggest limiting factor in the use of a computer or other equipment used for data reduction and processing is in the mind of the analyst who prepares a format for solving a problem. We cannot expect any mechanic who has tinkered with cars to service an ICBM weapon. We should not expect that a key punch operator or a desk calculator operator would be suitable to handle a computer, even with additional training. The analyst and programmer must have not only the mechanical facility to understand the capacity of the machine in its various operations, but even more important, have the imaginative capacity to reduce a problem into a set of organized components which can be handled within the limitations of the equipment. Using a computer for one type of routine operation usually will not be sufficient to warrant the rental cost of the machine, but constant searching of new applications and methods is needed to make the maximum use of the facilities. In short, the machine is no more valuable than the mind of the best human being directing its use; using inadequate human resources will make the computer that much more an expensive plaything.

In evaluating a computer system, it is difficult to consider individual problems, since there is an interrelationship between the part and the whole. No one aspect can be viewed without reference to the total use and the total use is a composite of the individual tasks. Nevertheless, we shall try to resolve our discussion into a few specific areas and see what considerations are needed in visualizing the role of the computer in a given application. In particular, we will look at the problems involving the machine, the data, the programming, and the analysis. In each case, the criteria for evaluating the alternatives will be cost, time and utility.

Machine Limitations

In all computers the basic elements include input-output units, memory, arithmetic unit, and controls. For each phase there is a minimum time required for performance, and the slowest feature is the principal limiting factor. While manufacturers pride themselves in making memory access or arithmetic operations a matter of milliseconds, the slowest part is still the input-output phase. Where the information is supplied the machine or answers are produced on punched cards, the rate of input-output may be so slow as to constitute the major portion of the machine time used for a particular problem. For tape feed systems, the input-output phase may be reduced considerably, but this usually requires tape-card converters to provide this time saving, at some additional expense. The time savings may be relatively great on solving a given problem, but if the total utilization of computer time is less than the maximum available, the net gain may be small. Output direct to an on-line printer is faster than card punching, but does not provide a record form which is usable in further operations. In planning machine use, therefore, careful attention should be given to the amount of time required for input-output operations relative to calculating time for an individual problem. Then an evaluation of the over-all utilization of the machine use will add the information which will indicate the need for streamlining the input-output system. Where an increase in efficiency is indicated, improvements in the card format will often provide the additional time savings without any major system changes. It must be remembered, however, that gains in machine efficiency may require additional handling of the data and add to the total cost of the operation. The undue attention given to improving the efficiency of machine use has been a major pitfall in the computing business, since in many cases this has necessitated the use of additional human resources. While it would be ideal to imagine a few hours of relatively low cost human labor might have saved considerable expensive machine time, it would be naive to assume this has been the case. Too often the copying and coding of data is done

by a skilled research worker who spends a lot of valuable "free" time in an effort to save a few dollars of "costly" machine time. Here we see the danger of the machine directing the use of human resources instead of the reverse situation. The important point is to know how to use the computer with these limitations to increase the efficiency of the most valuable resource. In all cases, cost, time and utility must be weighed in providing the optional solution.

Data Preparation

In designing the various components of a computer system, probably less thought was given to the data collection and preparation problem than any other aspect. It is true that the engineers tried to build a universally acceptable word size to fit the problems at hand, but they were not fully aware of the manner in which data are normally collected and tabulated. Most data are collected serially, either in a horizontal or vertical alignment. In the former case, we obtain many values for a single unit, such as in a questionnaire, while in the latter we collect all the measurements on one attribute for all units and then repeat the pattern for a second attribute, as in the case of growth measurements. Analyses, similarly, may involve only one variable at a time, or as in the case of correlation analysis several variables may be compared with each other.

From the computer viewpoint, data should be prepared so as to minimize input-output problems. This generally means recording values serially on a punch card. The normal method of tabulating values is usually in a vertical array with an identifying code accompanying each unit of information. If there are several attributes, these are recorded in parallel columns. The cost of card preparation is increased when the form in which data are entered on the card is other than the form in which the data are recorded. Either the card punching time is increased or the data have to be recopied.

In many cases the problem can be anticipated and an adjustment made to alleviate the difficulty. If the time and cost involved in recopying or the additional time in punching is great, compared with extra time involved in entering the data in a less efficient manner from the viewpoint of computer use, then it would be best to leave matters alone. Where it is possible to record data in a form which would simplify punching operations, then a change in the collection of initial information may be the best way to resolve the situation. In many cases, however, this will necessitate retraining of persons doing the field work or overcoming the inertia of "I don't see why we can't leave things alone" on the part of some individuals who are reluctant to make a change of any sort. It would be wise to remember that a change to "streamline" recording of

data for computer use might be an expensive one if its impairs the efficiency of the worker who is doing the actual work of assembling the information.

The relative cost of card punching or similar methods of data preparation for machine use is small per unit of information, but may be considerable in terms of the total cost of carrying out an analysis. In small projects, for example, half of the total cost may be in preparing data for the computer. Making more efficient use of the computer may save pennies and at the same time add dollars to the cost of card preparation. The most expedient system is to punch the data in a simple direct format from the code sheets or data collection forms and then reorganize the material to make use of standard input-output systems. The more diverse the use of a computer system, the more advantageous it will be to use standardized procedures rather than special purpose control panels. Only where a given type of problem is repeatedly encountered would it be profitable to provide special coding, punching, and operating procedures.

Here again we see that the time involved in use of the computer is only one consideration. The human resource and the machine time used in intermediate steps of data preparation are also important. While it is good economy to plan the steps of a computing operation to make the best use of the computer, the machine should not be the dominating feature of the organization.

Programming

The development of any system of instructions for obtaining the solution of a problem may be generally classed as programming. The system may contain verbal or symbolic elements in varying combinations and usually is only of casual interest to the person interested in the final solution of the problem. Preceding the age of the computer there was some interest in finding short-cuts in computing methods, but the system itself was usually a flexible arrangement which could be modified easily to take care of special situations. With the advent of the high-speed computer, a new trend developed which might be called programming for programming's sake. This philosophy was initiated by the computer manufacturers, who were interested in showing how efficiently the time for calculating could be used. Unfortunately, this concept became established in the instruction manuals and training of new programmers, and it has been difficult to convince the new generation that a gold-plated Model T really isn't what we want.

If we just remember that the purpose of the program is to produce an answer within the resource limitations and requirements of the problem, then there will be much less wailing and gnashing of teeth at the

costs of computing. If a problem is a one-time operation (and over half of all programs written for research problems are used only once), then a direct, simple set of instructions, which may make less than optimal use of the computer time, will be preferable to a super-streamlined highly efficient program which takes weeks to prepare and satisfies the aesthetic senses of the programmer, but creates frustration on the part of the customer. Where the program is for repeated use, some attention must be given to simplification, although this too can be overdone in light of the constantly changing emphasis on various aspects of a general situation.

Since we often want to look at several problems of similar interest, each requiring a slightly different set of computations, it is exasperating to learn that most programs have little or no flexibility as compared with the instructions used for desk calculator operations. To be able to take care of a large number of similar, related problems we can write a general program, but this often becomes a case of setting up a network of super highways for people who only want to be able to get to the corner grocery. By the time you have taken all the interchanges and made all the turns to get to your destination, you could have walked there and back. If a specialized program is written to take care of a particular type of problem, then it is frustrating to learn that it is very difficult to change even one instruction, which would provide additional information about a similar problem. This lack of flexibility might be termed a machine limitation, but I feel that man must remain versatile enough to handle the situation within the limitations of the machine, and this has not always been the case. Programming has developed to the stage where subroutines can be spliced together to make a workable unit, but the main difficulty still lies in the failure of man to develop the methodology to make the machines do his bidding without excessive restrictions.

Analysis

The great awakening in the computer business does not really dawn on the unsuspecting customer until he gets down to the analysis of the results. Where careful attention was paid to the few figures that could be easily obtained using pencil and paper, or the single page of results generated from the use of a desk calculator, open-eyed astonishment is the first reaction of the researcher on viewing the volumes of output from the computer. This ability to produce solutions to a series of simultaneous equations with error coefficients and a host of side figures is like opening Pandora's box—a lot more evil is often unloosed than the good which was produced. If you aren't sure of which parameters may be of interest, just crank out every possible combination (it takes only a few minutes more, is the usual assurance of the programmer) and "pick

the winner." You really don't need to think about the problem, just let the machine do it for you. Many will say this is not the fault of the computer, for all it does is follow instructions. We must remember, however, that no amount of purely empirical results will explain cause and effect relationships or the need to know why things behave in a particular way. Intuition can be a poor substitute for information, but a lot of data does not take the place of brains. Pilot studies and trial runs are part of every problem-solving routine. No one would say you can just think about any problem and evolve an answer without some calculation. The danger lies in letting the machine supply the motivation for an action rather than using the machine to determine the relative value of a given set of alternatives which we believe provide the answer to the problem.

In examining these four areas we have pointed out some of the potential trouble spots in a computer system. Two other points which should be mentioned are the need to consider the use of auxiliary equipment and the total time needed to provide a solution to a given problem.

In many applications, the computer is the central part of the system. The auxiliary equipment is used primarily to prepare data for the computer. The proportion of resources involved in the card handling equipment is small, and there seems to be little need to utilize these machines for a great many hours to pay for the rental cost. The point that is missed is that such equipment can frequently be used to supply the answers to given problems in only a slightly longer time than the computer, when total time for programming is considered for the different machines, and usually at considerably less cost. The thing to do is to use the computer for problems that cannot be handled by other equipment, rather than utilize the time of the computer fully, regardless of the job involved, in an effort to reduce cost per hour for the computer. An added incentive for the use of peripheral equipment lies in the general availability of these machines compared to the tight scheduling and backlog of work which often is characteristic of computers.

If you are interested in getting an answer, the time of consequence is from raw data to results, not the computing time alone. Where it takes only minutes to "solve" the problem on the computer, it may be days or weeks from initiation to solution. In some cases the cost may be about the same by alternative methods, but the total time may vary considerably. Again, we should be alerted to the need for selecting the machines to do the job with the least expenditure for *all* resources rather than allowing the prima donna of the operation to become the focal points for all problems.

When I bring up these matters at various times to the people who run computer centers or teach courses in computing methods, I am assured

that they realize all this and have revised their thinking accordingly. Unfortunately, I find that the output of personnel trained for computer work does not yet show the marks of this new approach. It seems to take a couple of years of getting one's hands dirty before one can understand how things work in the field, and how to make the machine do the work for the man, not vice versa. This may be an indictment of our education system in general, but I feel that in a dynamic field like computing, we are more in need of providing talent that can move easily from situation to situation without being tied to the strait jacket of conventional ways.

Where are the pitfalls? Everywhere, for the unsuspecting wearer of rose-colored glasses. The computer is a tool which has allowed men to raise their sights. For a space vehicle or an airways control system the problems are so vast we could not begin to handle the work without the computer. The cost is a small figure in proportion to the gains. For a working industry, the computer can be an asset when it cuts time and cost, provides information not available previously, and aids management in making decisions. The extent to which these results can be achieved at a realistic expenditure of resources depends on the clear thinking and careful planning of the people who use the computer. The trouble begins when we try to substitute the computer for man's reasoning ability.

CONSUMER PREFERENCE AND THE SUBSTITUTION OF MARGARINE FOR BUTTER

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THE substitution of margarine for butter has often been used as a prime illustration of price cross-elasticity. In both theoretical and empirical studies, the price factor has dominated the thinking and the analytical approaches adopted (see 6, 7, 8, 9, 10, 13).[1] By and large, however, the results using this approach, by itself, have proved inconclusive. For example, one rather intensive analysis into the phenomenon, using pre-World War II Swedish experience, concluded that those changes in fat consumption (i.e., from butter to margarine) . . . "can hardly be expected to be fully explained by the price and income development alone. . . . We cannot be expected to arrive at very reliable results on the basis of market statistics. . . . The results seem to confirm that margarine consumption in the inter-war period has been systematically influenced by other factors. . . . The negative results of [testing these factors] shows that the cross elasticities obtained are not in agreement with the general

[1] Numbers in parenthesis refer to items in the appended bibliography.

hypothesis that underlies the analysis" (13, pp. 284-287; 306; selected passages). Other investigators, using U.S. data have had similar experiences (e.g., 10). It is the purpose of this paper to briefly summarize some results obtained by adding to the price and other usual variables considered a factor whose relevance has not hitherto been investigated, namely, advertising expenditure.

Some Preliminary Considerations

Two aspects of price influences upon substitution may be distinguished: (1) price differences and (2) price ratios. With respect to the first aspect, logically one should expect positive correlation between price differences and consumption of the substituting commodity and a negative correlation between price difference and consumption of the commodity for which it is substituted. Preferably, the relations should be significant. The writer has calculated elasticities and second-order partial correlations for these commodities for the period since 1920 (excluding 1943-46 inclusive). The results are furnished in Table I. The Q's and P's stand for butter and margarine quantities and prices (deflated by the consumer price index) as annual averages. It is immediately evident that the correlations, both pre- and post-war, are insignificant and further, they are all positive. The elasticities are also confused. On the assumption that the commodities were independent of each other pre-war, both should show negative elasticities to their respective prices, and the reaction to price differences should be purely fortuitous. The relatively high standard errors indicate that this may be the case. But, on the contrary assumption, i.e. that the commodities are genuinely substitutable, the signs of the coefficients obtained are incorrect since they mean that, as the price difference widens, butter purchases increase and margarine

TABLE I. ELASTICITIES AND SECOND-ORDER PARTIAL CORRELATION COEFFICIENTS OF PER-CAPITA PURCHASES AND PRICE[1] DIFFERENCES OF BUTTER AND MARGARINE 1920–42 AND 1947–58

	1920–1942	1947–1958
A. *Elasticities*	Log $(P_B - P_M)$	Log $(P_B - P_M)$
Log Q_B	.3442	.404
	(.166)	(.231)
Log Q_M	−.4368	10.661
	(.428)	(11.185)
B. *Partial Correlations*	$(P_B - P_M)$	$(P_B - P_M)$
Q_B	.1839	.4994
Q_M	.1765	.3884

Source: (4) pp. 92–95; 104–107.
[1] Prices deflated by the consumer price index.

purchases fall. While greater logic would appear to attach to the elasticity coefficient for margarine in the post-war period (although the accompanying standard error makes it unreliable) that for butter is logically inconsistent inasmuch as margarine was replacing butter to a considerable extent at this time. The net effect of the investigation is to render doubtful the value of price difference as an explanatory variable, at least in this instance.

Similarly, the price ratio has proved somewhat unreliable (see 6, 7, 8, 9). Not only has this factor yielded undistinguished results (7, 9) but the whole conceptual basis which uses it as the foundation for calculating elasticity of substitution has been challenged (6, 8). Furthermore, with respect to these two commodities and their consumption in this country, the implication for consumer behavior implicit in the use of price ratios is extraordinary: non-acceptance of a commodity when it retails at half the other's price; acceptance when the price ratio reaches 40 percent of the other's price. It would imply an exceptional degree of price sensitivity on the consumer's part to price ratios and price changes and would leave the fundamental question untouched. This is not to say that consumers are unaware of or are unaffected by price ratios. They were and are. But consumers' willingness to act upon perceiving these facts depends upon the importance which the price ratio has for them. Thus, the price ratio becomes influential under certain psychological conditions, and would be uninfluential under others. In consequence, the role and function of consumer attitudes seems to be essential to an explanation.

The Factor of Sales Promotion

Additional considerations prompted attention to consumer attitudes. These derived from empirical research.

1. Questioning of consumers yielded the following information. First, many felt (in the post-war period) that butter's price was "too high." This concept does not appear to emerge only from a comparison with the price of margarine. For while the price ratio widened and the price difference did likewise, this would have affected only those consumers willing to alter their consumption habits. Put another way, there would have to be a psychological switch to margarine before a switch could register in the market place. Many consumers, indeed, remain wedded to butter regardless of price considerations. Furthermore, the price of butter had receded materially in the fifties from its post-war high (1948) and was not overpriced relative to other foods and its own pre-war level.

Second, consumers at all income, educational and occupational levels began to consume margarine. This suggested a common operative factor.

Third, a shift of major proportions in consumer usage and preference has taken place since the beginning of World War II, perhaps under the

TABLE II. BUTTER AND MARGARINE: PURCHASES AS PERCENT OF TOTAL FOOD FAT CONSUMPTION, RETAIL PRICE RATIOS (DEFLATED) AND ESTIMATED ADVERTISING EXPENDITURES IN ADJUSTED DOLLARS, 1947–1958

Year	Q_B as Percent of Total Food Fat Consumption	Q_M as Percent of Total Food Fat Consumption	Price Ratio P_B/P_M	Advertising Expenditure[1]	
				Margarine	Butter
				Million dollars	
1947	.267	.119	1.96	3.204	.478
1949[2]	.246	.135	2.34	6.614	.584
1950	.234	.133	2.21	5.613	.666
1951	.227	.156	2.34	5.636	.556
1952	.194	.180	2.89	4.319	.651
1953	.193	.183	2.69	6.151	.638
1954	.195	.186	2.43	6.738	.997
1955	.196	.178	2.46	6.689	1.494
1956	.193	.181	2.49	9.538	1.543
1957	.190	.193	2.48	11.302	1.574
1958	.182	.196	2.52	10.009	1.536

[1] Expenditures in million dollars deflated by *Printers' Ink* index of advertising costs, October 30, 1959.
[2] Data for 1948 not available.
Source: (4) pp. 262, 273.

influence of the rationing process, and it has been carried over into the post-war years (2, 3).

2. The margarine industry conducted very strong promotional efforts after the war, compared with relatively weak activity by butter interests. These efforts by the margarine industry revolved about the upgrading of the package as well as the quality of the product and the introduction of colored margarine. Moreover, both material and relatively insignificant changes and developments in margarine were trumpeted to the consumer via heavy advertising appropriations. A constant theme of much margarine advertising was the higher price of butter—the "high priced spread" idea.

In consequence it was decided to investigate the relative contributions of prices and advertising to the consumption of these two commodities, and a multiple regression was run using the data in Table II. The relationships were assumed additive and were of the form

$$Q_B(\text{or } Q_M) = a + b_{12}\frac{P_B}{P_M} + b_{13}\log Ad_M + b_{14}Ad_B$$

where:

Q_B and Q_M represent butter and margarine consumption as a percent of total food fat consumption, 1947–58 annual averages;

P_B/P_M is the ratio of annual average retail prices (deflated by the consumer price index);

Ad_B and Ad_M are annual advertising dollar expenditures for butter

and margarine as estimated by this writer, and adjusted by an index of advertising costs from *Printers' Ink*, October 30, 1959 (4, pp. 258, 271).

The results of the statistical investigation are furnished in Table III. Several salient points emerge from consideration of these results. First, the multiple determination coefficients and the corresponding multiple correlation coefficients are quite high. Decomposed into partial correlations, the price influence is revealed to be exceedingly high. The true nature of this particular datum is understood much better, however, if it is also indicated that similar pre-war correlations are fairly low. The relative prices of the two commodities therefore would seem to be of greater importance to consumers in the post-war period. Why? Is it possible that the significant correlation obtained for the influence of margarine advertising upon butter purchases ($r_{13.24}$) has any importance in this connection? More of this point presently.

Secondly, the regression coefficients are not completely logical, butter purchases for example, being negatively related to butter advertising. This may be explained, however, by the tremendously adverse trend of butter purchases during the period, so that this trend swamps most of the effect of the butter promotional effort. It also might be pointed out that heavy expenditure in behalf of butter begins relatively late in the decade, so that its effect might be less observable statistically. The same arguments, reversed, may be adduced to indicate why butter advertising should be positively related to margarine purchases. Aside from these two regressions, however, the others seem entirely consistent: we know that as

TABLE III. REGRESSION, BETA, MULTIPLE AND PARTIAL CORRELATION COEFFICIENTS CALCULATED FROM DATA IN TABLE II

Statistic	Butter (as Percent of Total Food Fat) Q_B	Margarine (as Percent of Total Food Fat) Q_M
$b_{12.34}$	−.078 (.011)	.070 (.013)
$b_{13.24}$	−.052 (.029)	.054 (.034)
$b_{14.23}$	−.018 (.010)	.017 (.012)
$B_{12.34}$	.667	.631
$B_{13.24}$	.299	.323
$B_{14.23}$	.292	.287
R^2	.901	.857
R	.949 (.008)	.926 (.009)
$r_{12.34}$	−.927*	.996*
$r_{13.24}$	−.729*	.504
$r_{14.23}$	−.532	.456

* Significant at the 5 percent level or better.
Source: (4) chapter VII.

TABLE IV. DIRECT AND INDIRECT EFFECTS OF THE INDEPENDENT VARIABLES ON THE MULTIPLE CORRELATION OF BUTTER AND MARGARINE PURCHASES, 1947–1958

Effect	P_B/P_M	Log Ad_M	Ad_B	Total
	A. Butter Purchases			
Direct	.445	.089	.085	.619
Indirect				
X_2 & X_3	.038	.038		
X_2 & X_4	.046		.046	
X_3 & X_4		.072	.072	
Total Indirect	.084	.110	.118	.312
Total Effect	.529	.199	.203	.931
	B. Margarine Purchases			
Direct	.398	.104	.082	.584
Indirect				
X_2 & X_3	.039	.039		
X_2 & X_4	.043		.043	
X_3 & X_4		.076	.076	
Total Indirect	.082	.115	.119	.316
Total Effect	.480	.219	.201	.900

Source: (4), Chapter VII.
Note: This table examines and summarizes the percentage contribution of each variable investigated to the overall coefficient of multiple determination. Technique and method of presentation from (5) Chap. XII.

margarine's competition began to tell, butter became more price sensitive, displaying the usual negative relationship to price as indicated in Table III. That the regression of the price ratio upon margarine purchases is positive is evidence that consumers react not so much to margarine's price as to that of butter. Furthermore, in a substitutional situation such as this, it is to be expected that the signs for the substituting commodities be opposite.

Can the increased price sensitivity of butter be linked to the significant partial correlation obtained between butter purchases and margarine advertising? This point was raised above. Based upon the statistical analysis, it is contended that this may be the case, to an appreciable extent, at least. The Beta coefficients lend some support to this hypothesis, while additional assistance is furnished by the analysis outlined in Table IV. From this Table it appears that the price effects are largely direct while those of the advertising variables are largely indirect. It is recognized that no excessive reliance can be placed upon statistical correlations involving advertising expenditures and consumption, and especially when only eleven observations are involved. However, when the statistical evidence fits into a mosaic formed by other information (see 4, chap. VII) it lends it more credence. These other bits of evidence may be summarized as follows:

1. Consumers, when questioned, showed themselves to be more responsive to the price of butter than to the price of margarine (3, pp. 14-15; 2, pp. 23 ff). The basic reason for not buying butter, according to the consumers interviewed, was that butter's price was "too high." Consumers bought butter in large quantities when the price fell. This attitude may be related to the next point.

2. Margarine advertising has made much of the argument that butter is "the high priced spread," especially since the end of the war. Some consumer awareness of relative prices *may* be attributable to this effort.

3. Margarine advertising has played up, in considerable detail and at considerable cost, new developments in the packaging, flavor, taste, color, composition, etc. of the product. That these were not without impact upon consumers can be seen from the well-known history of the Delrich "squeeze bag" margarine package, which lofted a relatively minor brand into leadership contention within two years of its introduction.

4. Margarine spent considerable energy in promoting itself via consumer premiums and deals, while butter's efforts in this direction were negligible.

5. Butter received a good deal of adverse publicity during the early fifties when, due to Federal price support programs as well as declining domestic consumption, surplus butter stocks rose considerably although the price declined only slightly at the retail level. The inability of the U.S. government to reduce these stocks, even as ghee for India, found a good deal of newspaper space as well.

6. Much of margarine's promotional effort was directed toward dietitians, physicians, home economists, etc., in an effort to convince these molders of opinions about the virtues of margarine. It is interesting to speculate about the possible number of converts to margarine made by having recipes begin "Take a cup of butter or margarine . . ." (see 4, chap. VII).

7. Some sociological investigation has tended to indicate that advertised brands (and hence advertising per se) possess great importance for the wives of workingmen (11, pp. 207 ff). "The advertiser who succeeds in presenting a strong image of his product, as a well-known and popular national brand has an advantage with these people [wives of workingmen]. They will see his brand as trustworthy in a market which they believe is full of uncertain values." (11, p. 208).

It may be argued that the correlative results obtained indicate just as readily the value of success: that is, margarine firms spend more and more on promotion because of increasingly widespread consumption of the product which enables them to do so. It does not seem possible statistically to investigate the sequential arrangement of cause and effect. On the whole, it might be pointed out, margarine firms seem convinced,

on the basis of their private studies, of the effects of their promotional efforts upon their competitive positions vis-a-vis each other. Reasoning from such considerations suggests the conclusion that at least some overall effects upon the consuming populace may emerge from their joint efforts.

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PLACEMENT OF AGRICULTURAL ECONOMICS B.S. GRADUATES

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ONE of the primary ingredients of success for any undergraduate teaching program is favorable placement of their B.S. graduates. Departments of Agricultural Economics have always prided themselves on the broad base of training in their undergraduate curricula that permits graduates to move into a large variety of occupational opportunities. A look at curricula changes in the past several years in Schools of Agriculture would particularly show a "liberalizing" of course requirements. In most cases, Departments of Agricultural Economics have led the way. At Purdue University, the department attempts to offer a basically "liberal" program within the School of Agriculture.

Job placement, of course, is primarily the responsibility of the grad-

uating senior and not the University. However, an active role by the department in helping to "merchandise" its graduating seniors will be effort well expended. As part of its placement function, the Purdue department has recently attempted to analyze what its graduates are doing and has prepared a brochure around this topic. This brochure has received plaudits from businessmen, who essentially say that the University staff has finally learned something about good advertising. In addition, placement information and comments from businessmen and alumni aid in curricula evaluation.

What Graduates Are Doing

In the eleven years 1950 to 1960 inclusive, 366 men graduated from the School of Agriculture at Purdue University with a major in the Department of Agricultural Economics. In a mail survey, 301 returned questionnaires indicating their current type of employment, salary and other general information. The summary includes 280 of these men (Table 1). Twenty-one involuntarily serving their military obligation were excluded.

Farm-oriented occupations

Fourteen percent (39) of the graduates were owner-operators or tenants on farms. Another 3 percent (8) were professional managers. Studies at Pennsylvania State University[1] and Cornell[2] indicate 12 and 11 percent, respectively, of graduates engaged in farm management. The figure of about one graduate in seven or eight returning to the farm seems to be fairly typical. Professional managers reported average incomes of $7,600.

Five percent were engaged in county extension service work. This compares with Penn State and Cornell both reporting 6 percent. Average salaries were only slightly above $5,000 in the Purdue group.

Careers in finance

Forty-nine (17 percent) of the total were pursuing careers in finance. Eighteen were with commercial banks, 19 were employed by various insurance companies, and seven were with a government-related financial institution such as a Production Credit Association, National Farm Loan Association, Federal Intermediate Credit Bank, or Farmers' Home Administration. Other occupations in finance were associated with real

[1] Includes 258 graduates from Agricultural Business and Management as compiled in 1961 annual summary, mimeo, Dept. of Agr. Econ. and Rur. Soc., Pennsylvania State Univ.

[2] H. S. Tyler, "Occupations in 1959 of Men Who Received the Bachelor of Science Degree in 1949 and 1954, New York State College of Agriculture," *Farm Economics*, Cornell Univ., Ithaca, N.Y., No. 218, Oct. 1960, pp. 5822-3.

TABLE 1. OCCUPATIONS AND SALARIES IN 1960 OF 280 B.S.A. GRADUATES WHO MAJORED IN THE DEPARTMENT OF AGRICULTURAL ECONOMICS, 1950–60 INCLUSIVE, PURDUE UNIVERSITY[a]

Employment	(Number)	Number	Percent of Total	Average Salary
Farm Oriented		65	23.2	$5604
Owner-operator or tenant	(39)			
Professional farm manager	(8)			
County extension service	(14)			
Soil conservation service	(4)			
Finance		49	17.5	$7038
Commercial banks	(18)			
Insurance companies	(19)			
Government related agencies	(7)			
Commercial credit, real estate, etc.	(5)			
Industry—Farm Supply		31	11.1	$6477
Feed and seed	(16)			
Farm equipment	(12)			
Other	(3)			
Industry—Processing and Food Distribution		27	9.6	$6737
Retail food	(7)			
Grain and vegetable processing	(6)			
Meat and meat products	(5)			
Cooperatives	(5)			
Other	(4)			
Industry—Non-agriculturally Related		47	16.8	$7091
Gas and oil	(6)			
General merchandise	(4)			
Auto and auto accessories	(4)			
Building, machinery, appliances, lumber, transportation	(10)			
Other	(23)			
Other		61	21.8	—
University teaching, research, extension	(8)			
Other professions	(5)			
Private industry or government research	(10)			
Military career	(4)			
Communications and trade associations	(8)			
High school teaching	(5)			
USDA	(10)			
Graduate study	(11)			
Total		280	100.0	—

[a] Total graduates numbered 366.

estate, farm loan, and commercial credit agencies. Commercial bank salaries averaged $6,389 while those employed with insurance companies were averaging $7,487. Penn State reports 7 percent working with credit agencies and insurance companies. Cornell reports 13 percent.

Farm supply industries

Thirty-one graduates (11 percent) were employed in the farm supply industry. Most of these were salesmen representing feed, seed, machinery,

fertilizer, pharmaceutical, and other farm supply firms. Occupations as salesmen, fieldmen, sales promotion manager, field representative, were included.

Food marketing and distribution industries

Twenty-seven, or slightly over 10 percent, were employed in food processing and distribution industries. Their jobs included buyers, brokers, and managers of retail food stores, wholesalers, salesmen, and production foremen. Some were owners or part owners in food distribution firms.

Nonagriculturally related business

Forty-seven (17 percent) were working in businesses not directly related to agriculture. However, part of those reported in the financial careers area could also be considered as non-agriculturally related. About half of these 47 individuals were salesmen. They were working in general merchandise, lumber, automobiles, chemicals, gas and oil, pharmaceutical, dental supplies and soap product manufacturing firms. The others held such diversified occupations as manpower planners, social workers, personnel specialists, transportation specialists, computers' programmers, air traffic controllers, and various forms of management training positions.

Other

Of the remaining 61 graduates, 41 were pursuing careers in research, teaching, communications, or with trade associations. These include men on college staffs, those doing graduate work, and those doing research with industry. Five were teaching in high schools. Fifteen others were in government service: nine with the United States Department of Agriculture, two with state and local government, and four as military career men. Five were in the professions of medical doctor, dentist, lawyer, and veterinarian. The Cornell University report indicates 13 percent alone in college teaching, research or administration, while Penn State reports a like percentage of professional agricultural economists.

Salary Advancement

The average beginning salary for a graduate in the last year or two is about $5,200 (Table 2). There appears to be about $800 difference between the average salaries of those who have been out one to five years and the new graduate, and $1,800 difference between those out five to ten years and those out one to five years. This indicates that salaries tend to increase at an increasing rate for this time period. While it appears in Table 2 that the man with the advanced degree does not have a salary

TABLE 2. AVERAGE 1960 SALARIES BY YEAR OF GRADUATION OF 241 B.S.A. GRADUATES WHO MAJORED IN DEPARTMENT OF AGRICULTURAL ECONOMICS, PURDUE UNIVERSITY[a]

Year	Including Advanced Degrees		Excluding Advanced Degrees		Advanced Degrees	
	Number	Average	Number	Average	Number	Average
1950	27	8179	22	7802	5	10437
1951	19	8237	16	7882	3	10250
1952	29	8234	24	8060	5	8958
1953	20	7989	18	8013	2	—
1954	9	8091	6	7750	3	9000
1955	18	7737	17	7403	1	—
1956	15	6597	14	6719	1	—
1957	26	5680	22	5583	4	6062
1958	27	5782	25	5676	2	—
1959	23	5715	22	5696	1	—
1950–54	104	8161	86	7929	18	9466
1955–59	109	6739	100	6099	9	7014
1960	28	5397[b]	28	5397[b]	0	—
All Years	241	6903	214	6714	27	8338

[a] Excludes military (non-career), graduate assistants, and those not reporting salary.
[b] Excluding one man in this group reduces average to $5,200.

differential as large as one might expect, it should be remembered that the advanced degree holders reported for 1950, e.g., received their advanced degrees later than 1950. There is, of course, some limitation to the salary data in that it is difficult to assess the value of fringe benefits, etc. In addition, those who were working as farm owners or operators may have computed their income in several ways.

Progress of Graduates

In addition to favorable placement in a job upon graduation, the kind of progress graduates make over time, particularly in comparison with the non-agricultural graduate is important. Evidence is mixed. A survey by Dean D. C. Pfendler of 16 firms hiring many college men gave mixed opinions. About a third of the firm personnel managers indicated that the generally more specialized training of agricultural graduates helped them to attain promotions more rapidly than non-agriculture graduates but worked in reverse as the agricultural graduates became candidates for administrative positions involving wide areas of responsibility.[3] Where this is the case, the emphasis on more liberal type curricula in Departments of Agricultural Economics should help to overcome this difficulty. In terms of salary, a college graduate can probably expect to double his

[3] D. C. Pfendler, "Agricultural vs Non-Agricultural Training as Related to Progress in Industry," unpub. mimeo, Purdue Univ., School of Agriculture.

starting salary in 10 years. Those now earning about $8,000 who graduated in 1950-54 probably started at about $4,000 (Table 2). Pfendler's survey would also substantiate this general conclusion.

Placement Procedure

College staffs need to be more active in aiding their graduates in placement. Extension personnel are continually in contact with firms who may or may not be aware of the training an undergraduate receives when majoring in Agricultural Economics or Business Management. Senior seminar class instructors should require that each man prepare a vita for himself which he can reproduce easily and use effectively in procuring a job. Men in personnel who hire college graduates indicate they want a man who can read and write (communicate), think, and get along with people. Particularly those firms with training programs are not looking for "specialists."

Summary

There seems to be little doubt that B.S. graduates from Schools of Agriculture with majors in Agricultural Economics or related curricula move into extremely diversified occupations. In general, the survey of the Purdue graduates in the period 1950 to 1960 indicates that about one-fifth return to farm-oriented occupations, another fifth go into agriculturally related industries, another fifth into non-agriculturally related businesses, a fifth into financial careers, and a fifth into other occupations which are primarily professional. Of the 280 reporting data for this study, 27 men held 40 advanced degrees.

COMMENTS ON "DETERMINING THE OPTIMUM REPLACEMENT PATTERN"[1]

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IN HIS recent paper Faris[2] presented a criterion for determining the optimum duration of "enterprises" that are of a sequential nature: "The optimum time to replace is when the marginal net revenue from the present enterprise [*production period*] is equal to the highest amortized present value of anticipated net revenue from the following enter-

[1] *Editor's note:* The authors of this "Comment" originally submitted a longer manuscript offering a general treatment of the subject dealt with in Mr. Faris' article, which they had prepared before the latter became available to them. The "Comment" is a condensation of this manuscript, revised to focus upon significant differences in formulation of the problem and in certain conclusions regarding its solution.

[2] J. E. Faris, "Analytical Techniques Used in Determining the Optimum Replacement Pattern," *J. Farm Econ.*, 42:755-66, Nov. 1960.

prise [*production period*]." The italics denote our change in terminology: we use "enterprise" to denote the activity (e.g. raising hogs) and "production period" to denote the time which elapses from the initial application of variable inputs to the date of marketing of the product (the time to put through a batch of hogs). We find this change helpful in our dual objectives of:

(1) Providing a more general alternative formulation of the problem, which appears to be useful in dealing with questions relating to production, time, and profit; and

(2) Suggesting corrections for apparent errors in the formulation and application of the Faris' criterion.

The conditions which give rise to the problem have often been recognized.[3] Since the biological phenomenon of growth is involved in all of agriculture's production processes, production takes place over time, and from the time it is initiated until the time it is stopped the successive application of inputs results in a sequential change in the proportions among inputs prior to the emergence of the product. This situation differs in a critical way from industrial production, where in the absence of price changes, there will be fixed relative magnitudes of input and output flows.[4] In effect this difference means that although continuous industrial production may be regarded as taking place at a single point on a production function, continuous production in agriculture embodies a movement along the production function as a production period progresses.

To the extent that a production period uses time that could be used for its successor (the possible use of time and other inputs in alternative enterprises is considered separately), the periods compete with one another not only for physical resources but also for time. It is therefore necessary to establish an appropriate criterion for determining the optimum duration of a production period. The Faris' criterion involves discounting for time preference. We consider two situations: the first assuming a zero rate and the second assuming a positive rate of time preference proper (both assuming constant factor and product prices and positive external rates of interest). This procedure emphasizes the crucial conceptual distinction between opportunity cost and time preference. Op-

[3] See, for example, K. E. Boulding, *Economic Analysis* (New York: Harper & Brothers, 1958), pp. 818-28; G. K. Goundrey, "Forest Management and the Theory of Capital," *Canadian J. Econ. and Pol. Sci.*, 26:439-51 Aug. 1960; and P. L. Hansen and R. L. Mighell, *Economic Choices in Broiler Production*, USDA, Washington, D.C., Tech. Bul. 1154, 1956.

[4] "Production functions are relationships between time flows, and not between timeless stocks. Output is output per hour or year, and inputs are not laborers or machines or acres, although we often refer to them in such terms for convenience, but the services of a laborer, or a machine, or an acre, for the specified time period. Production is a process, not an act, and its time dimension cannot be neglected."—G. J. Stigler, *The Theory of Price* (New York: The Macmillan Co., 1954), p. 109.

portunity costs refer to alternative income-earning possibilities, and these are considered in both situations. Time preference proper is preference for income in one time period rather than in another, and this will be considered only in Situation II.

Situation I: No Time Preference Proper

A few definitions are essential:

n is the duration of a production period;
v is gross revenue per period;
c is variable cost per period;[5]
f is fixed cost per period, and may be regarded as the cost of initiating a production period;
π is profit per unit of time.

$$\pi = n^{-1}(v - c - f) \tag{1}$$

$$\frac{d\pi}{dn} = -n^{-2}(v - c - f) + \left(\frac{dv}{dn} - \frac{dc}{dn} - \frac{df}{dn}\right) n^{-1}. \tag{2}$$

Since $df/dn = 0$, setting $d\pi/dn = 0$, yields

$$\frac{dv}{dn} - \frac{dc}{dn} = \frac{(v - c - f)}{n}. \tag{3}$$

Condition (3) implies that maximum profit per unit of time requires the equivalence of marginal net rate of return per unit of time and average net rate of return per unit of time.[6]

The relationship between this condition and the more familiar equality between marginal value product and marginal factor cost can be shown by a simple transformation. Since input is taken up over time, its level, $x = g(n)$, is a function of time per production period. Direct application of the rule for the derivative of a function of a function permits equation (3) to be rewritten as

$$\frac{dv}{dx}\frac{dx}{dn} - \frac{dc}{dx}\frac{dx}{dn} = \frac{(v - c - f)}{g^{-1}(x)} \tag{3'}$$

which is of course equivalent to

$$\frac{dv}{dx} = \frac{dc}{dx} + \frac{dn}{dx}\frac{(v - c - f)}{n}. \tag{4}$$

[5] Both c and f embody appropriately compounded interest charges that permit costs to be compared with revenues which are assumed to occur at the end of a production period. These interest charges are the opportunity costs or the foregone earnings of the next most profitable alternative to this enterprise. In this sense it is the external rate of return and consequently is not necessarily equal to the market rate of interest.

[6] This is the same result presented by Boulding, *op. cit.*, and Faris, *op. cit.*

This will be recognized as the usual condition of equivalence between marginal value product and marginal factor cost. However, it will be noted that the cost of employing another unit of input is not just the "usual" marginal factor cost dc/dx, but also the foregone earning (internal rate of return) of the time required to employ that unit in the present production period. Since dn/dx is the time required to apply the unit of input, and $(v-c-f)/n$ is the average rate of return per unit of time from the profit maximizing length of production periods, the time opportunity cost of applying an additional unit of input in the present production period is the product of the time required to apply the input, multiplied by the maximum attainable rate of return per unit of time.

For sequential production of the type under discussion it may be concluded that true marginal factor cost is greater than dc/dx by the quantity

$$\frac{dn}{dx}\,\frac{(v-c-f)}{n}$$

which implies that for maximum profit per unit of time, the optimum amount of variable input is less than that implied by the "usual" equivalence of marginal value product and marginal factor cost.[7]

Up to the present no consideration has been given to the problems which arise when time is required to stop one production period and start another. Such a waiting time may reasonably be regarded as one of the costs of increasing the number of periods in any time interval. We define $n_w = n + W$, where W is a constant waiting period.

When n_w is substituted into equation (4) the result may be rewritten as

$$\frac{dv}{dx} = \frac{dc}{dx} + \frac{dn_w}{dx}\,\frac{(v-c-f)}{n_w}. \tag{5}$$

Since

$$\frac{dn_w}{dx} = \frac{dn}{dx}, \quad \text{and} \quad \frac{(v-c-f)}{n_w} < \frac{(v-c-f)}{n} \quad \text{for} \quad W > 0$$

it may be inferred that the effect of a constant waiting period between production periods is to reduce the average rate of return per unit of time for any value of n and increase the optimal length of a production period.

The same results presented mathematically above are shown diagrammatically in Figure 1: ABO and CD are total revenue and total cost functions, respectively. The line O_1F shows the time required to employ a given level of input. (In passing it might be noted that although O_1F as drawn exhibits a constant increment in input per unit of time, it could well be drawn to show level of input as an increasing or decreasing func-

[7] Crops grown in temperate regions would be exceptions.

tion of time without changing the general results. Furthermore the distance OO_1 corresponds to a waiting time between production periods.) By means of O_1F, profit as a function of level of input in quadrant III is transformed to $GH_1H_2H_3$, a function of time in quadrant I. It will be observed that although profit is maximized at time OK_2,[8] profit per unit

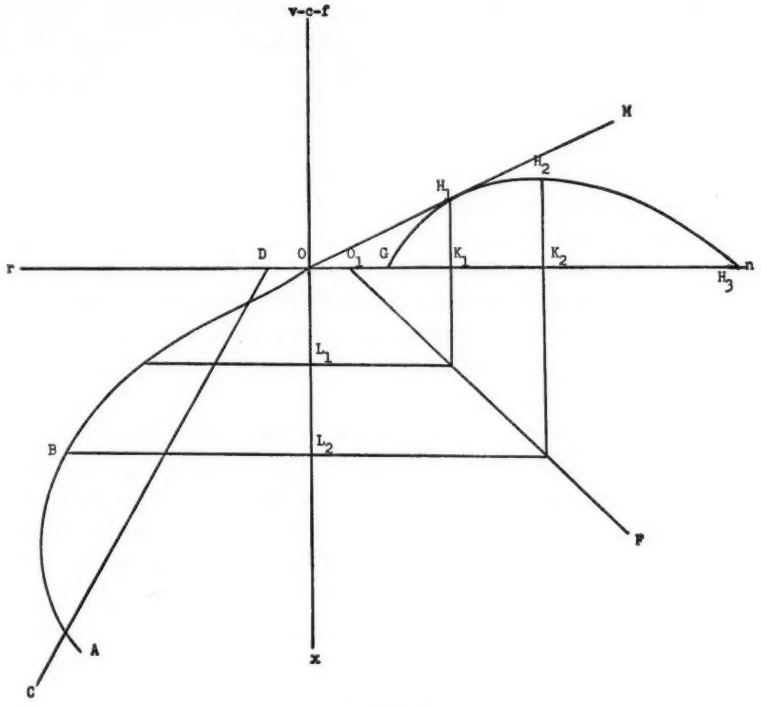

FIGURE 1

of time $(v-c-f)/n$ is maximized sooner, at time OK_1.[9] This means that OL_1 rather than OL_2 is the appropriate amount of variable input x to employ.

In effect the argument implies that questions such as "how heavy should I feed my hogs," or "when should I market my broilers" are answered incompletely and perhaps incorrectly when the answers are based on considerations that pertain to a single production period, i.e., profit maximization per lot of hogs or broilers as the case may be. It would appear that more complete and more adequate answers will of necessity involve some consideration of lengths of production period.

[8] Since the slopes of ABO and CD are equal at this time, i.e., $dv/dx = dc/dx$.

[9] Since the slope of OM which is equal to $v - c - f/n$ is the same as the slope of $GH_1H_2H_3$, which is $d(v - c - f)/dn$.

The only instances where these considerations can be neglected occur when the production function under consideration is in some sense timeless.

Situation II: Time Preference Proper

Time preference is simply preference for income in one time period rather than in another,[10] and this is usually taken to mean a preference for current over future consumption. Obviously, the concept relates to the utility function, and thus to the desired pattern of consumption and income flows, rather than to opportunity costs. Faris regards time preference proper as being equivalent to opportunity costs,[11] or alternative income-earning possibilities. The marginal rate of time preference is the slope of an indifference curve relating present to future consumption. Thus time preference is no more a function of opportunity costs than the slope of an isoquant in production economics is a function of the slope of a budget line. In equilibrium the slope of the budget line will be tangent to an indifference curve or isoquant as the case may be. But time preference proper requires that the slope of the indifference curves along the 45° line be other than minus unity.

Time preference proper and opportunity costs will be examined as they bear upon the problem of maximizing profit per unit of time. Opportunity costs are the earnings foregone when one enterprise is selected rather than alternative investment opportunities. These foregone earnings constitute the external rate of interest which has to be charged as a cost of the enterprise selected. If the relevant costs are appropriately compounded at the external rate of interest and the net payoff remains positive, the enterprise is worth selecting because it offers a higher rate of return than can be obtained elsewhere.

Is it then meaningful to discount this positive net future payoff back to the present?[12] The three discount rates from which one has to be selected are (a) internal rate of return, (b) external rate of return, (c) time preference proper. Internal rate of return is an inappropriate choice that implies double counting in the sense that maximizing internal rate of interest is an alternative criterion to maximizing net profit per unit of time.[13] On the other hand external rate of return would not be particularly useful since it has already been charged as a cost to the enterprise and

[10] Boulding, *op. cit.*, p. 751.

[11] Faris, *op. cit.*, p. 758.

[12] We agree with Faris that discounting for market and production uncertainties, while important, may be set aside here as not involving an ordinary discounting formula.

[13] It should be noted that Goundrey, *op. cit.*, pp. 447-8, argues rather convincingly that maximization of the internal rate of return might be the appropriate criterion for a forestry enterprise which is generally a large scale business. This criterion is not identical with maximizing the income stream except in the simplest case.

there does not seem to be a great deal to be gained from charging it a second time. Time preference proper would seem to be the only reasonable rate at which to discount the future net payoffs. The only *a priori* reasons for supposing a positive rate of time preference ($r > 0$) appear to be: (1) the entrepreneur regards the probability of his demise as constant in any year (if r is constant) and hence considers his chances of collecting a payoff at the end of a long interval less probable than at the end of a short interval; or (2) the entrepreneur, as a consumer, wishes to bring his income flow more closely into line with his consumption expenditures. The first reason for the existence of time preference appears to have little relevance for the large corporation, and may be offset on the part of the individual entrepreneur by a desire to provide for the future. The second reason may be handled as purely a problem of consumption to be solved in terms of consumer credit, in which case maximum net profit per unit of time (i.e., repayment capacity) seems a reasonable goal for the production process.

Once the net payoffs have been discounted back to the present the resultant lump sum has to be converted into a stream of receipts and a value has to be selected for the time for each production period so that the maximum flow of receipts per unit of time is obtained. The procedure in the general case[14] is outlined as follows:

P is the net payoff of each period, i.e., $(v-c-f)$;
n is the time required per period as defined previously;
t is the number of production periods;
θ is equal to tn;
r is time preference discount rate.

Let $(1 + q) = (1 + r)^n$ for $n \geq 1$, i.e., $q = (1 + r)^n - 1$.
Since the net payoff P may be regarded as an annuity, the present value of the stream of payoffs is given by:

$$\text{(1)} \qquad \text{Present value} = \left[\frac{(1+q)^t - 1}{q(1+q)^t}\right] P.$$

When the stream of payoffs is limitless

$$\text{(2)} \quad \lim_{t\to\infty} (\text{present value}) = P \lim_{t\to\infty} \left[\frac{1 - \dfrac{1}{(1+q)^t}}{q}\right] = \frac{P}{q} = \frac{P}{(1+r)^n - 1}.$$

This present value is in the form of a lump sum, however, and hence must be converted into a stream to get the flow per period. This is ac-

[14] Since production periods may be short or long depending on the enterprise selected, it seems useful to examine the general case where the stream of payoffs is limitless.

complished by multiplying it by the amortization formula. It follows that the value of this flow per period is given by:

$$A = \left[\frac{P}{(1+r)^n - 1}\right]\left[\frac{r(1+r)^\delta}{(1+r)^\delta - 1}\right]. \tag{3}$$

However this stream should also be regarded as being limitless, hence[15]

$$\lim_{\delta\to\infty} A = \left[\frac{P}{(1+r)^n - 1}\right] \lim_{\delta\to\infty}\left[\frac{r}{1 - \frac{1}{(1+r)^\delta}}\right] \tag{4}$$

$$= P\left[\frac{r}{(1+r)^n - 1}\right] = A^*.$$

Since A^* is already the appropriately formulated flow of profit per period of time, all that is required is to select an appropriate value of n so that A^* is maximized.[16] The method followed here is to take the first derivative of A^* with respect to n, set it equal to zero and solve for the general condition. The steps are:

$$\frac{dA^*}{dn} = \frac{d\left[\frac{rP}{(1+r)^n - 1}\right]}{dn} \tag{5}$$

$$= \left[\frac{dP}{dn}\frac{1}{P} - \frac{(1+r)^n \ln(1+r)}{(1+r)^n - 1}\right] rP[(1+r)^n - 1]^{-1}.$$

Setting $dA^*/dn = 0$ and cancelling $rP[(1+r)^n - 1]^{-1}$ yields

$$\frac{dP}{dn} = P\left[\frac{(1+r)^n \ln(1+r)}{(1+r)^n - 1}\right] = P\left[\frac{(1+q)\ln(1+q)^{1/n}}{q}\right]$$

which may be rearranged as

$$\frac{dP}{dn} = \frac{P}{n}[(1+q)\ln(1+q)^{1/q}]. \tag{6}$$

The general condition for the optimal rate of flow of profit per unit of time when there is time preference proper is thus given by equation (6), which states in effect that marginal net rate of return per unit of time must equal average net rate of return per unit of time multiplied by the

[15] A^* is the same formulation obtained by Faris, *op. cit.*, p. 761, even though founded on a limitless horizon, i.e., net payoff multiplied by the sinking fund formula, with the exception of course that Faris' r is not time preference proper.

[16] It will be observed that the procedure used here to maximize A^* by setting $dA^*/dn = 0$ and solving for the general condition differs from the procedure chosen by Faris, *op. cit.*, p. 763, namely that of inspection of a preselected set of values of n.

constant $(1 + q)\ln(1 + q)^{1/q}$. For a positive time preference interest rate, i.e., $r > 0$, the constant is greater than one. Hence the existence of time preference proper implies a *shorter* production period than that indicated when profit is maximized over time in the absence of time preference proper as in situation I. It is worth noting that in the absence of time preference proper this condition is identical with the one previously formulated,[17] $dP/dn = P/n$ or its equivalent $dv/dn - dc/dn = (v-c-f)/n$. The proof of this last proposition is as follows:

$$\lim_{r \to 0} q = \lim_{r \to 0} (1 + r)^n - 1 = 0 \tag{7}$$

$$\lim_{q \to 0} (1 + q) = 1 \tag{8}$$

$$\lim_{q \to 0} (1 + q)^{1/q} = e \quad \text{and} \quad \ln e = 1. \tag{9}$$

Consequently

$$\lim_{r \to 0} (1 + q) \ln (1 + q)^{1/q} = 1.$$

Section III: A Comparison of Criteria

In order to compare the criterion given in (6) above with that presented by Faris, it is necessary to formalize the latter and solve a dimensionality problem. Reasoning apparently by analogy, Faris[18] concludes that the optimal replacement pattern is achieved when the marginal net revenue in the present production period is equal to the maximum value of the amortized stream of receipts from the next period.[19] Formally, his criterion is:

$$\frac{dP}{dn} = A^* \max, \quad \text{where} \quad dn = 1.$$

It is obvious that to proceed by analogy from the condition for maximizing P/n, namely $dP/dn = (P/n)\max$, to a supposed condition for maximizing A^*, namely $dP/dn = A^*\max$, is generally fallacious. At first glance, Faris' argument would appear to avoid this difficulty in that the values compared, dP/dn and $A^*\max$, refer to different production periods. Essentially his notion is this: if the present realizable increment in net payoff, dP/dn, exceeds the present worth of the next most profit-

[17] Faris, *op. cit.*, footnote 8, p. 762, attempts to show that discounting may be neglected for short production periods. Unfortunately this assumes that as $n \to 0$, $r \to 0$, which is untrue for either time preference proper or opportunity costs. Even if this assumption were true, Faris' expression has a limiting value 0/0, which is indeterminate, and hence not equal to $1/n$

[18] Faris, *op. cit*, p. 761.

[19] Faris offers no proof that this is an appropriate criterion.

able use of that time, A^*max, it pays to continue the current period. This sounds plausible: indeed, one is inclined to suspect that it is its very plausibility which accounts for Faris' acceptance of a result which maximizes neither P/n nor A^* (as his data reveal) and which seeks to adjust for a preference for current over future receipts by postponing the average date for realization of receipts (since beyond (P/n)max, as n increases, P/n declines). Faris' error lies not in his choice of viewpoint, for it is that of a true marginalist, but in his apparently incorrect specification of the real value of the currently realizable increment in net payoff. He neglects the fact that continuation of the current period involves a conflict with time preference: to forego realization of net receipts, P, for one more "year" is to incur a reduction in "utility" roughly equal to rP. In other words, the entrepreneur requires $(1 + r)P$ at the end of the "year" under consideration to compensate him for the P now foregone; if there is to be any net gain from waiting, the promised payoff at the end of the "year", $(P + dP)$, must exceed $(1 + r)P$. Therefore, the real value of the currently realizable increment in net payoff is approximately $(dP/dn) - rP$.

The approximation serves to demonstrate that Faris violates his own concern with time preference. A problem of dimensionality stands in the way of transforming the approximation into a precise statement: whereas dP/dn is defined for $dn \to 0$, the above formulation implies $dn = 1$, a "year," or the interval of time for which the interest rate is defined. Two propositions will now be established:

I. The precise real value of the currently realizable increment in net payoff, for purposes of comparison with A^*max is

$$\frac{r}{\ln (1 + r)} \frac{dP}{dn} - rP, \qquad \text{for } dn \to 0.$$

II. When the precise value in I is equated to A^*max the result is the original condition for the maximization of A^*, which confirms that the value of n determined by maximizing A^* is the correct one.

I. The amortization formula generated the value A^* which implicitly, therefore, occurs at the end of the "unit" interval. The "unit" interval is that for which the interest rate is defined; it is some multiple, N, of dn. Thus $Ndn = 1$. For comparison with A^* it is necessary to construct K, the real value of the increment in net payoff realizable in the unit interval, from its elements of magnitude γ, where $\gamma = (P + dP) - (1 + r)^{dn}P$ at the end of any dn. Altogether, by the end of the unit interval there will be

$$K = \gamma + (1 + r)^{dn}\gamma + (1 + r)^{2dn}\gamma + \cdots + (1 + r)^{1-dn}\gamma$$

where $(1 \quad dn) = (N-1)dn$, so that $Ndn = 1$, and

$$K = \gamma\left[\frac{(1+r)^{N\,dn=1} - 1}{(1+r)^{dn} - 1}\right] = \gamma\left[\frac{r}{(1+r)^{dn} - 1}\right]$$

$$= [(P + dP) - (1+r)^{dn}P]\left[\frac{r}{(1+r)^{dn} - 1}\right]$$

$$= [dP + (1 - (1+r)^{dn})P]\left[\frac{r}{(1+r)^{dn} - 1}\right]$$

$$= \left[\frac{r}{(1+r)^{dn} - 1}\right] dP - rP = \left[\frac{rdn}{(1+r)^{dn} - 1}\right]\frac{dP}{dn} - rP$$

$$= \left[\frac{r}{\dfrac{(1+r)^{dn} - 1}{dn}}\right]\frac{dP}{dn} - rP.$$

Now

$$\frac{(1+r)^{dn} - 1}{dn}$$

$$= \frac{1 + rdn + \dfrac{dn(dn-1)}{2!}r^2 + \dfrac{dn(dn-1)(dn-2)}{3!}r^3 + \cdots}{dn} - \frac{1}{dn}$$

$$= r + \frac{dn-1}{2!}r^2 + \frac{(dn-1)\,(dn-2)}{3!}r^2 + \cdots$$

and

$$\lim_{dn \to 0} \frac{(1+r)^{dn} - 1}{dn} = r - \frac{r^2}{2} + \frac{r^3}{3} - \cdots = \ln(1+r)$$

$$\therefore \lim_{dn \to 0} K = \frac{r}{\ln(1+r)}\frac{dP}{dn} - rP.$$

II. The precise value of K has just been derived; it is to be equated to $A^*\text{max}$.. It has been shown that if A^* is to be maximized the following condition must be satisfied:

$$\frac{dP}{dn} = P\left[\frac{(1+r)^n \ln(1+r)}{(1+r)^n - 1}\right]$$

or, alternatively,

$$P = \frac{dP}{dn}\left[\frac{(1+r)^n - 1}{(1+r)^n \ln (1+r)}\right].$$

Substitution of this value of P into the general expression for A^*,

$$A^* = P\left[\frac{r}{(1+r)^n - 1}\right]$$

yields

$$A^* \max = \frac{dP}{dn}\left[\frac{(1+r)^n - 1}{(1+r)^n \ln (1+r)}\right]\left[\frac{r}{(1+r)^n - 1}\right]$$

$$= \frac{dP}{dn}\left[\frac{r}{(1+r)^n \ln (1+r)}\right].$$

Then, setting $K = A^*\max$ is equivalent to setting

$$\frac{r}{\ln (1+r)}\frac{dP}{dn} - rP = \frac{dP}{dn}\left[\frac{r}{(1+r)^n \ln (1+r)}\right]$$

whence

$$\frac{dP}{dn}\left[\frac{1}{\ln (1+r)} - \frac{1}{(1+r)^n \ln (1+r)}\right] = P$$

or

$$\frac{dP}{dn} = P\left[\frac{(1+r)^n \ln (1+r)}{(1+r)^n - 1}\right].$$

Conclusion

It has been suggested earlier in this paper that when movement along a production function is concomitant with the passage of time, the opportunity cost of applying another unit of input is not only its marginal factor cost as usually defined in static economics, but also the foregone earnings of the time required to apply the unit of input. The statement and examination of some of the logical consequences of this time opportunity cost are the main contributions of this paper. Of the two criteria examined, the one for maximizing net profit per unit of time in the absence of time preference proper appears to be more important than the one embodying time preference proper. Although the criterion is not new, since it was clearly enunciated at least as long ago as 1948, its relation to the ordinary profit maximizing criterion does not appear to have been stated explicitly elsewhere.

If despite considerations stated previously there is time preference proper that can be satisfied only by recourse to a modification of the criterion for maximizing profit per unit of time, then the magnitude of the modification depends on the level of the time preference interest rate, and whether the production period is normally short or long. In the presence of time preference proper it has been demonstrated that the relevant criterion is the one which maximizes A^* which is:

$$\frac{dP}{dn} = \frac{P}{n}\left[\frac{(1+r)^n \ln (1+r)^n}{(1+r)^n - 1}\right].$$

The expression in brackets has been shown to approach 1 as $r \to 0$; otherwise it is greater than 1. Consequently the maximization of A^* when $r > 0$ requires that $dP/dn > P/n$, which means a shorter production period than required by the criterion for maximizing profit per unit of time.

The significance of this result can readily be shown by an examination of Faris' forestry data. The values in the following table are drawn from Faris' Tables 2 and 3, except those which appear in the $(dP - rP)$ column. The latter have been calculated from the appropriate data presented by Faris but they represent the approximation to the concept of "real value of currently realizable increment in net payoff," the concept which Faris might have used but did not.

n	A^*	dP	$dP - rP$	P/n
40	\$4.85	\$21.55	\$10.74	\$9.16
43	4.96	18.05	5.33	9.86
45	4.92	15.68	1.98	10.14
48	4.74	11.11	− 3.72	10.30
53	4.21	5.00	− 10.95	10.03

Faris shows A^* a maximum at the end of year 43. The adjustment factor for P/n at the end of this year is 1.77, which implies that dP should equal 1.77 P/n. The actual value of ndP/P is 1.83 suggesting that the maximum A^* occurs somewhat later than the end of the 43rd year. What is important to note, however, is that $(dP\text{-}rP)$ is approximately equal to A^* in the 43rd year, greater than A^* in the 40th year, and less than A^* in the 45th year. The correct place to stop is thus approximately five years before year 48 (when P/n is a maximum) and not five years later as Faris concludes.

ON DETERMINING THE OPTIMUM REPLACEMENT PATTERN: A REPLY

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THE preceding comments by Winder and Trant take issue with the methodology presented in an earlier paper by myself concerning the optimum time to replace certain types of assets.[1] This reply will be primarily confined to discussing the areas of disagreement. However, in addition, some clarification of the procedures that they have set forth is needed.

Winder and Trant do not disagree with the technique that I used in determining the optimum replacement when a zero discount rate for time preference is assumed. In fact their discussion of "Situation I: No Time Preference Proper" is more or less a repetition of that contained in my earlier paper plus several ramifications. One ramification that is of special interest is that of expressing the optimum replacement in terms of the marginal value product and marginal factor costs. This might be expressed as,

$$MVP = MC_f + MC_t$$

where MC_f is the marginal cost of the inputs other than time and MC_t is the marginal cost (opportunity cost) associated with time. This formulation will be referred to later in this reply.

In "Situation II: Time Preference Proper," Winder and Trant first discuss the concept of time preference. They state that I regard time preference proper as being *equivalent* to opportunity costs. What I actually said was that time preference is *primarily a function* of opportunity costs. This is an important distinction, although it should be explicitly stated in terms of the *discount rate* for time preference. It is agreed that "the marginal rate of time preference is the slope of an indifference curve relating present to future consumption." But what determines the point that the individual selects on his subjective indifference curve? Obviously income is a primary factor. The size, distribution, composition and certainty of expected income are very important in determining the discount rate for time preference. Opportunity costs (income possibilities) associated with various investment alternatives are important in the determination of the *long-run* discount rate for time preference. In my earlier paper a positive discount rate was assumed only in the long-run situation, i.e., only for the replacement enterprise (production period) for trees.

[1] J. E. Faris, "Analytical Techniques Used in Determining the Optimum Replacement Pattern," *J. Farm Econ.*, Nov. 1960, pp. 755-66.

A zero discount rate for time preference was assumed for the present enterprise (production period). The implications of these assumptions will become evident later in this paper.

The authors succeed in deriving the sinking fund formula in equation (4) (p. 946). In equations (5) and 6) they derive the condition that holds when A^* is maximized. This is

$$\frac{dP}{dn} = P\left[\frac{(1+r)^n \ln (1+r)}{(1+r)^n - 1}\right].$$

However, the sinking fund formula which is used to express P in terms of an amortized value (A^*) is,

$$A^* = P\left[\frac{r}{(1+r)^n - 1}\right].$$

Therefore, the problem is to convert the right side of the former equation into the above equation. This can be accomplished as follows:

$$\frac{r}{\ln (1+r)} \frac{dP}{dn} = \frac{Pr\,(1+r)^n}{(1+r)^n - 1}$$

and subtracting r from each side of the equation,

$$\frac{\dfrac{r}{\ln (1+r)} \dfrac{dP}{dn}}{P} - r = \frac{r(1+r)^n}{(1+r)^n - 1} - r.$$

But we know that

$$\frac{r(1+r)^n}{(1+r)^n - 1} - r = \frac{r}{(1+r)^n - 1},$$

therefore

$$\frac{r}{\ln (1+r)} \frac{dP}{dn} - rP = P\left[\frac{r}{(1+r)^n - 1}\right]$$

when A^* is a maximum.

What does the above imply and/or assume? *First,* it implies that the adjusted marginal net revenue,

$$\frac{dP}{dn}\left[\frac{r}{\ln (1+r)}\right] - rP,$$

must equal the maximum amortized value, maximum A^*, in the same year in the production process for both the present and the following enterprises (production periods). *Second,* it assumes that the discount

rate for time preference must be the same in the short run (for the present enterprise) as it is in the long run (for the immediately following enterprise). *Third,* it implies that the physical, cost, and price relationships must be identical for the present and following enterprises.

Does this invalidate the general principle of optimum replacement set forth in my earlier paper? This is that *the optimum time to replace is when the marginal net revenue from the present enterprise is equal to the highest amortized present value of anticipated net revenue from the enterprise immediately following.* The answer is *no.* In fact the "Comments" by Winder and Trant, if anything, strengthen the validity of this general principle. In essence they have presented a special case of the general principle stated above. In the original paper it was assumed that the short-run discount rate for time preference was zero. That is, the net returns from the present enterprise were not discounted at the beginning of the year when the operator made the decision of whether or not to replace the present stand of trees. The equation expressing the optimum replacement in terms of the marginal value product and marginal factor costs might be useful in illustrating the logic in discounting for time preference. This was expressed as

$$MVP = MC_f + MC_t.$$

The *MVP* might be discounted for time preference but the appropriateness of this and the rate to be used depends upon the present circumstances in which the operator finds himself. I agree with Winder and Trant, although they did not mean it in this restricted sense, that the discount rate with respect to the *MVP* would probably be zero in most instances. However, if a positive discount rate for time preference appears appropriate it is doubtful if the short-run discount rate (for the *MVP*) would necessarily be identical to that used for the long run.[2] If the operator finds himself in a circumstance where he needs funds in a hurry his discount rate for time preference in the short run might be quite high. For example, in the timber illustration a discount rate of only 5 percent for time preference in the short run would result in a *MVP* of approximately \$3.24 $(dP/dn - rP)$ in year 40. The maximum A^*, using the long-run discount rate of 3 percent, is \$4.96.

The MC_f needs no explanation. The MC_t is determined by the expected flow of income from the following enterprise, thus the maximum amortized value of the expected income is the correct value to use for this term when $dn = 1$; the discount rate for time preference to be used in the long run is still a subjective consideration. However, it will probably be as great as or greater than the rate of return on a relatively safe investment such as bank savings or bonds.

[2] Winder and Trant assume a 3 percent discount rate for time preference for the short-run period and also for the long-run period.

The reason that Winder and Trant became confused in assuming that their special case is a general statement is that they attempt to carry the analogy of the *MNR* being equal to the *ANR* in the same year in the production process from the short production period (feeder cattle) to the long production period (timber). Although space prohibits me from indicating the actual results the application of their special case to such enterprises as cling peaches, where the income from the present enterprise is a flow rather than a lump sum, proved to be quite unsatisfactory. In addition, the year when $MNR = ANR$ occurred *before* the year that the maximum A^* was obtained.

One additional comment made by Winder and Trant in footnote 17 deserves special attention. They indicate that an expression presented in my earlier paper,

$$\lim_{r \to 0} \frac{r(1+r)^n}{(1+r)^n - 1},$$

"has a limiting value 0/0 which is indeterminate, and hence not equal to $1/n$." This statement is incorrect. L'Hospital's rule should be applied to a function taking on an indeterminate form.[3] When this rule is applied,

$$\lim_{r \to 0} \frac{r(1+r)^n}{(1+r)^n - 1} = \frac{1}{n}.$$

[3] L'Hospital's rule for evaluating the indeterminate form 0/0 is to differentiate the numerator for a new numerator and the denominator for a new denominator; the value of this new fraction for the assigned value of the variable will be the limiting value of the original fraction.

DISTRIBUTED LAGS, TECHNOLOGICAL CHANGE, AND THE DEMAND FOR FERTILIZER

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OF THE puzzles confronting economists, none is, perhaps, of greater significance than whether the phenomenon of technical change can be abstracted from in econometric models. Griliches' study of the demand for fertilizer is of interest in this connection, since it represents a bold attempt to bring the troublesome problem within the province of economic analysis.[2]

While it would be nice to have a simple explanation of technical

[1] The opinions expressed in this paper are those of the author and do not necessarily represent the views of the Farm Economics Research Division, Agricultural Research Service, U. S. Department of Agriculture.

[2] Zvi Griliches, "The Demand for Fertilizer: An Economic Interpretation of a Technical Change," *J. Farm Econ.*, 40:591-606, Aug. 1958.

change, considerable doubt can be raised as to whether the distributed lag approach to demand and supply estimation or any statistical model employing time series data really adds to our understanding of agricultural progress. Room for doubt is particularly apparent if one: (a) compares the results of alternative methods of fitting the same type of equation used by Griliches, both for the whole period and for subperiods; (b) fits an alternative equation not involving the lagged dependent variable; and (c) tries to reconcile the empirical results with experimental findings.

Our first suspicion that one might be in error in attributing most of the increase in United States fertilizer consumption to a 50 per cent decline in relative price stems from the fitting procedure. If (similar)[3] data for 1911-1958 are fitted directly, with the dependent variable expressed as a first difference [Equation (3)], an r^2 of only .376 is obtained (see Table 1). The indirect method of fitting [Equation (5)], typically used to eliminate the first difference in the dependent variable, yields an r^2 of .977—60 percentage points greater.

The rather large difference suggests that if the results are naively compared with the static regression of fertilizer consumption on relative price, which yields an r^2 of .662, there is danger that the unsophisticated analyst will reject the dynamic approach to demand analysis if the direct estimating procedure is used—that is, if Equation (3) is fitted—and accept it if the indirect method of estimation, Equation (5), is used. The former action, of course, would be equally as erroneous as the latter, since the fitting procedure in no way affects the coefficient of adjustment or the long-run price elasticity, which are of concern to the economist (see Table 1 for a comparison).

Griliches recognizes this point[4] by suggesting that the r^2's he obtains in estimating the demand for fertilizer should be taken with a grain of salt but then goes on to imply[5] that, with a simple model, "a lot is explained."

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[3] The results obtained in Table 1 are not the same in all respects as those obtained by Griliches for the period 1911-1956 owing to: (a) the use of the U. S. Department of Agriculture's published price index rather than the price paid per plant nutrient unit, (b) the inclusion of two additional observations, and (c) the possibility of clerical errors in the basic data which I was unable to detect. Equation (5) of this paper is, however, sufficiently similar to Equation (3), Table 1, of Griliches' paper, *ibid.*, p. 602, to suggest that the functional instability observed in the data published by Brake, King, and Riggan (*op. cit.* in Table 1), would be more or less the same for Griliches' unpublished data.

[4] Griliches, *op. cit.*, p. 603.

[5] *Ibid.*, p. 605. My reason for stressing the r^2 illusion, which by now is pretty well recognized if not emphasized by econometricians working with distributed lags, is a feeling that it has kept the profession from being critical of otherwise implausible results.

TABLE 1. REGRESSION RESULTS: UNITED STATES DEMAND FOR FERTILIZER, 1911–1958[a]

Period and equation number	Coefficients of relative price of fertilizer	Coefficients of lagged dependent variable	r^2	Coefficients of adjustment	Elasticity of long-run demand
1911–1958					
(3)	− .432 (.083)	− .128 (.035)	.376	.128 (.035)	−3.38
(5)	− .432 (.083)	.872 (.035)	.977	.128 (.035)	−3.38
	−1.973 (.208)		.662		
(6)		1.010 (.029)	.963		
1911–1933					
(5)	− .631 (.161)	.731 (.132)	.661	.269 (.132)	−2.35
	− .459 (.245)		.143		
(6)		.632 (.168)	.402		
1933–1958					
(5)	− .125 (.047)	.921 (.021)	.995	.079 (.021)	−1.58
	−1.718 (.287)		.599		
(6)		.962 (.015)	.994		

[a] All variables are expressed as natural logarithms of the original values. The figures in parentheses are the calculated standard errors.

Sources: The basic data pertaining to fertilizer are taken directly from John R. Brake, Richard A. King, and Wilson B. Riggan, *Prediction of Fertilizer Consumption in the United States, the East North Central Region and the South Atlantic Region*, N. C. State College, Dept. Agr. Econ., A. E. Info. Ser. No. 75 (Raleigh, March 1960), App. Table 1, pp. 47–8. It was assumed that the 1916 index of fertilizer price was in error by (+1,000). After adjusting for what seemed an obvious recording error, the fertilizer price index was divided by an index of average prices received by United States farmers for all farm products (1910–14 =100); the years 1953–1958 were obtained from U. S. Dept. of Agriculture, "Agricultural Prices and Parity," *Major Statistical Series of the U. S. Department of Agriculture, How They Are Constructed and Used*, Agr. Hb. No. 118, vol. 1 (Washington, 1957), p. 14.

Equations (3) and (5), strictly speaking, are not comparable. The dependent variable in (3) is a first difference, whereas (5) is often considered a trend equation. Generally, economists have been much more successful, in the sense of obtaining higher r^2's, in explaining time series with a growth component than in explaining year-to-year or period-to-period changes. The reason one should hesitate to compare correlation coefficients in these two instances is that, while growth series may yield

a higher r^2, there would seem to be greater opportunity to obtain a spurious correlation, inasmuch as most economic series are closely related and subject to about the same kind of trend.

That trend is an extremely important component of the fertilizer data is illustrated by Equation (6), which, except for the omission of price, is the same as Equation (5). The omission of price reduces the total r^2 very little; .977 is not spectacularly different from .963. We cannot reject, it seems to me, the hypothesis that the total explanation in Equation (5) is being divided up arbitrarily among similar trends.[6]

When the data are broken down into subperiods, 1911-1933 and 1933-1958, a great deal of instability is observed. The coefficients attached to relative price differ by a factor of four; the coefficients of adjustment likewise differ by a factor of four–falling from .269 for the period 1911-1933 to .079 for the more recent period 1933-1958. The estimated elasticity of long-run demand for fertilizer is only −1.58 for the period 1933-1958, whereas the elasticity suggested by the longer period 1911-1958 was −3.38–twice as large as the more recent estimate.

The rather large difference in elasticities suggests, if one is inclined to force a rational explanation, that the demand for fertilizer does not have the logarithmic relationship assumed by Griliches.[7] This point is worth pursuing, since most investigators seeking a simple relationship between yields and fertilizer have settled for a polynomial rather than a Cobb-Douglas production function.[8] The derived demand curve, which can be obtained by taking the first derivative of the fertilizer response relationship ($y = a_0 + a_1x - a_2x^2$) and setting it equal to the relative price of fertilizer, is linear, not logarithmic.[9]

Although it is possible to imagine an aggregation of linear micro-parameters that would be logarithmic at the macro level, there is no a priori reason for assuming a natural transformation. The relationship Griliches observed in the aggregate time series data on fertilizer consumption might as easily be attributed to shift parameters as to a special case of linear aggregation.

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[6] The price variable is, judging by the subperiods, working against itself. During the subperiod 1911-1933, it acts to enhance the coefficient attached to lagged fertilizer consumption; during the subperiod 1933-1958, it depresses the coefficient attached to the lagged dependent variable.

[7] Griliches, *op. cit.*, p. 596.

[8] Paul R. Johnson, "Alternative Functions for Analyzing a Fertilizer-Yield Relationship," *J. Farm Econ.*, 35:519-29, Nov. 1953. See also *Economic and Technical Analysis of Fertilizer Innovations and Resource Use* (Ames: The Iowa State College Press, 1956), John T. Pesek and John R. Webb, pp. 15-18; David C. Hurst and David D. Mason, pp. 207-16; and R. L. Anderson, pp 187-206.

[9] For a step-by-step derivation, see Harold O. Carter, Gerald W. Dean, and Chester O. McCorkle, Jr., *Economics of Fertilization for Selected California Crops*, Univ. of California, Giannini Foundation Mimeo. Rept. No. 230 (Berkeley, 1960), pp. 32-34.

In order to demonstrate this possibility, as well as the fundamental difficulty faced by all students of technical change, I have arbitrarily selected two of the most plausible shift variables—acre-feet of irrigation water and acreage planted to hybrid corn lagged five years—and have included them in a linear demand function for fertilizer along with the number of livestock on farms as of January 1.

A number of studies have suggested that moisture has an important bearing on the profitability of fertilizer application.[10] Between 1920 and 1959, the total tonnage of fertilizer used annually in California, where nearly all crops are grown on irrigated land, increased thirty fold compared with a threefold national increase. The state of California now uses 10 per cent of all the fertilizer applied in the United States, yet has only 3 per cent of the nation's cropland.[11]

The importance of hybrid corn as a variable shifting the demand for fertilizer has been aptly summarized by Heady and Yeh:

> In pre-hybrid days, over most of the corn belt, the region which has moved into first place in total quantity of nutrients purchased by farmers, soil fertility generally was not the limiting factor in yields; but in post-hybrid days it became so. Research on seeding rates and rotations has led to higher fertilization rates even in the last ten years.[12]

The results obtained by including irrigation water and hybrid corn in the United States demand for fertilizer are summarized in Table 2. The multiple r^2 is .975, which compares favorably with an r^2 of .977 obtained by fitting Equation (5) in the logarithmic form to the same data (see Table 1). Interestingly enough, the relative price of fertilizer turns out to be the least significant variable from a statistical viewpoint. While this result is surely as extreme in the opposite direction as Griliches' suggestion that most increases in fertizer consumption can be explained in terms of a decline in the real price of fertilizer, it can easily be argued that price is not necessarily the most important variable determining fertilizer consumption.

It has been estimated, for instance, that 25 per cent of the food produced during World War II can be ascribed to the efficient use of fertilizers as recommended on the basis of field plot experiments, soil tests, plant tissue tests, greenhouse tests, and observations by trained agronomists.[13] Following the same all-or-none type of reasoning, it is

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[10] Johnson, *op. cit.*, pp. 524 and 525; R. J. Hildreth, "Influence of Rainfall on Fertilizer Profits," *J. Farm Econ.*, 39:522-3, May 1957; Jack L. Knetsch, "Moisture Uncertainties and Fertility Response Studies," *J. Farm Econ.*, 41:70-6, Feb. 1959.

[11] Carter, Dean, and McCorkle, *op. cit.*, p. 1.

[12] Earl O. Heady and Martin H. Yeh, "National and Regional Demand Functions for Fertilizer," *J. Farm Econ.*, 41:336, May 1959.

[13] *Economic and Technical Analysis . . .*, p. 226.

TABLE 2. ALTERNATIVE DEMAND FUNCTION FOR FERTILIZER, UNITED STATES, 1911–1958[a]

Coefficient of				
Relative price of fertilizer	Number of livestock on farms	Acre-feet of irrigation water	Acreage planted to hybrid corn lagged five years	r^2
(1)	(2)	(3)	(4)	(5)
− 5.997 (254.391)	− .294 (7.256)	31.187 (4.900)	34.808 (5.289)	.975
−5084.685 (779.684)				.480

[a] All variables are expressed as their original values. The figures in parentheses are the calculated standard errors.

Sources:

Col. 1: Same as for Table 1.

Col. 2: U. S. Dept. of Agriculture, "Agricultural Production and Efficiency," *Major Statistical Series of the U. S. Department of Agriculture, How They Are Constructed and Used*, Agr. Hb. No. 118, vol. 2, (Washington, 1957), p. 39, and U. S. Dept. of Agriculture, *Agricultural Statistics, 1959* (Washington, 1960), p. 307.

Col. 3: Walter Picton's estimates of daily average water use (including delivery losses but not including reservoir evaporation) converted to million acre-feet per year and interpolated linearly—see U. S. Bureau of the Census, *Statistical Abstract of the United States, 1958* (Washington, June 1958), p. 165.

Col. 4: Millions of acres planted to hybrid corn is taken from various issues of *Agricultural Statistics* and arbitrarily lagged five years.

probably safe to infer that at least a third of our present agricultural output can be attributed to commercial fertilizer. In 1958, expenditures for fertilizer and lime were estimated at only $1.3 billion, less than 6 per cent of total production expenses. Considering the essential nature of plant nutrients and the fact that fertilizer constitutes only a small proportion of total expenditures, it follows, resorting to Marshallian logic, that the demand for fertilizer must be inelastic and that price within the range observed during the last 50 years is not the most important variable determining fertilizer consumption.

If price were the most important variable, it would be difficult to explain the fact that from 1910 to 1940 the Appalachian, Northeast, Southeast, and Mississippi Delta regions used 90 per cent of all chemical fertilizer. It would also be difficult to explain why the United States, in contrast to Japan and Europe, uses very little fertilizer per acre of cropland harvested.

That the long-run demand for fertilizer is inelastic, other things equal within the range of contemporary optimality, is attested to by the demand curves that have been derived from fertilizer response relationships. This author has calculated an elasticity for both corn and potatoes in the Central Valley of California and found them to be in the neighborhood

of −.25.[14] In contrast, it might be noted that Griliches obtained elasticities ranging between −2.57 and −3.23 for aggregate fertilizer consumption in the Pacific area.[15]

Turning to an evaluation of the remaining variables, it should be noted in passing that the livestock index has a negative sign, as one would expect if natural fertilizer is a substitute for chemical fertilizer. Its lack of statistical significance can probably be attributed to the fact that livestock numbers have changed very little since 1911; in 1911, the index stood at 101, while in 1958, it was only 108. During the entire period, it ranged from a low of 95 in 1938 to an all-time high of 120 in 1944.

The statistical significance of irrigation water and hybrid corn is not surprising, since their trends are very nearly the same as the trend in fertilizer consumption. The simple r^2's between fertilizer consumption and these two independent variables compare favorably with the r^2 obtained by fitting the logarithmic trend relationship suggested by Equation (6); they are .947, .952, and .963, respectively, for acre-feet of irrigation water, acreage planted to hybrid corn, and fertilizer consumption lagged one year.

The coefficient attached to hybrid corn is not too implausible, since corn is now our most important consumer of fertilizer.[16] The coefficient attached to irrigation water does not make sense if a literal interpretation is attached to it, since more fertilizer is attributed to irrigation water than could possibly have been used on irrigated farms. In order to give a rational meaning to the coefficient obtained, one would need to consider the irrigation variable a proxy for a host of genetic improvements tending to shift the demand for fertilizer to the right at about the same rate at which the federal government has developed reclamation projects.

The genetic factor, which cannot adequately be quantified owing to the existence of "hybrids and hybrids," is of particular interest, since experimental results indicate that variety is often more important than mere fertilizer.[17] Inasmuch as it costs no more to apply a given quantity of fertilizer to a high-yielding variety than to a low yielder, the economic decision could, in many instances, turn entirely upon the development of plants which make better use of fertilizer.

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[14] Calculated from data presented by Carter, Dean, and McCorkle, *op. cit.*, pp. 35 and 48.

[15] Griliches, "Distributed Lags, Disaggregation, and Regional Demand Functions for Fertilizer," *J. Farm Econ.*, 41:94, Feb. 1959.

[16] U. S. Dept. of Agriculture, *The Economic Position of Fertilizer Use in the United States*, Agr. Info. Bul. No. 202 (Washington, 1958), p. 6.

[17] W. S. Colvin, "New Short Wheats," *Crops and Soils*, vol. 1, no. 7, April-May, 1949, pp. 18-19; D. P. Satchell, "It Takes More Than Fertilizer," *Plant Food Review*, vol. 3, no. 3, fall, 1957, pp. 10-13 and 31; H. D. Morris, A. A. Fleming, and G. M. Kozelnicky, *The Influence of Fertilization and Variety on Corn Yields in the Georgia Piedmont*, Ga. Agr. Expt. Sta. Bul. N. S. 55 (Athens, 1958), p. 9.

My purpose in presenting the results depicted in Table 2 is not to argue that they are meaningful but to demonstrate how easy it is to obtain inferences which are diametrically opposite to those which have been published and to caution against accepting an oversimplified explanation of technical change.[18] The colinearity existing between relative price and other plausible shift variables is simply too great for one to place much confidence in the parameter estimates that can be obtained from time series data relating fertilizer consumption to possible explanatory variable.

[18] That it is misleading and possibly even dangerous to look upon the yield improvements of the last two decades as though they are a simple trend phenomenon is suggested by Japanese rice yields, which are unique in that improvements can be traced back to about 1883. Trends have been fitted to the data, but they obscure six fairly extended subperiods (1878-1884, 1885-1902, 1903-1913, 1914-1929, 1930-1954, and 1955-1960) exhibiting little or no trend; intervals of 18, 11, 16, and 25 years separate startling jumps in average rice yields of 23, 17, 12, 9, and 21 per cent.

DISTRIBUTED LAGS, TECHNOLOGICAL CHANGE, AND THE DEMAND FOR FERTILIZER: A REPLY

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REPLICATION of experiments is a very important scientific tool which is not used enough in economics. To be fruitful, however, it should be applied to a new or different body of data since an infinite number of alternative hypotheses will be consistent with the same data at conventional significance levels. Rather than testing my hypothesis against a new piece of data, Renshaw has chosen to present an alternative hypothesis that also fits these old data. Since the alternative hypothesis is not attractive from a theoretical point of view, is not superior statistically, and leads to implausible coefficients, I see no reason to change my original hypothesis.

In what follows I would like to comment on a few specific points raised by Renshaw in about the same order as they appear in his paper:

1. The R^2 illusion is by now well recognized in the literature. I was, in fact, the first one to draw attention to it in the paper under discussion (see [1], p. 603). This is why in subsequent papers (e.g., [4]), I present estimates of partial correlation coefficients for all the variables and also include trend in all the equations. There is a learning process involved for all of us working in this area.

2. A very important point is brought out when we compare Renshaw's equations (3) and (5). In (3) much of the high R^2 is due to the correlation of the dependent variable with itself lagged. In (5) this correlation is

eliminated, the R^2 drops precipitously, but the coefficient of price remains unchanged and so does its significance level. Thus, the "performance" of the price variable is independent of the high and perhaps "spurious" serial correlation in the dependent variable. (This point too was first made by me [3], p. 186.)

3. Nevertheless, equation (3) "explains a lot" of the rise in fertilizer consumption. Equation (5) shows that we do not do nearly as well in explaining the variance in the annual rate of increase of fertilizer consumption, but we did not claim to do it. The two equations, however, *are* comparable. In either case, the residual unexplained variance is the same but we are measuring it against different yardsticks.

4. The equation presented in Renshaw's Table 2 is not very satisfactory either as a comparison to mine or on its own merit. It is not strictly comparable since it is linear rather than logarithmic and employs what I believe to be a distinctly inferior price-of-fertilizer variable. The "manure" variable is insignificant and the other variables have implausibly large coefficients. Moreover, the "work" of the hybrid corn variable must be due to other reasons than those ascribed to it. The large increases in fertilizer used on corn in the Corn Belt have come after World War II. The increases in the hybrid corn percentage in that same period are coming, however, from the spread of hybrid corn in the South and on the fringes of the Corn Belt. The Corn Belt itself was planting over 90 percent of its corn to hybrid seed by the end of World War II. Thus the increases in fertilizer used on corn and in the percentage of corn planted to hybrid seed were occurring at different times and in different regions and while correlated are not related. This does not mean that the use of hybrid seed has had no stimulating effect on fertilizer consumption, only that it cannot be measured in the way Renshaw does it.

5. The Marshallian logic on the size of elasticities is correct only in the fixed-proportions derived-demand case, which is certainly not the case with fertilizer. Nor is it really relevant for demand functions that hold the price of the product and of other substitutes constant, or for "real" price of fertilizer demand functions with the product price in the denominator. The *a priori* size of the price elasticity is clearly not independent from what is being held constant in defining the particular demand function.

6. The only different data that Renshaw refers to are relationships derived from experimental fertilizer response data. But these are clearly not comparable, being neither generated by the actual behavior of farmers nor comparable in the populations for which the relationships are defined. It would be very interesting to explore why in this, as in many other cases, "actual" and experimental data give very different results, but this is not the occasion for it.

My hypothesis about the importance of price relationships in explaining some (not all) of the history of fertilizer use in this country is supported by similar results derived subsequently from regional data, from data on fertilizer use on cotton, and from a cross-sectional analysis of fertilizer use by States (see [2], Table 1). Moreover, an equation fitted to the virtually trendless 1911-1933 period predicted the subsequent developments very well. To argue against my hypothesis Renshaw would have to assert that the U.S. would have experienced the same tremendous increase in fertilizer consumption if the real price of fertilizer were a hundred percent higher. Renshaw does not say this, nor does he subject his model to any of the afore-mentioned tests, since it is not presented in earnest.

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REVIEWS

Changes in the Market Structure of Grocery Retailing, Willard F. Mueller and Leon Garoian. Madison: University of Wisconsin Press, 1961. Pp. 215, $6.00.

The authors state that they had two objectives in writing this book: (1) To describe the changes that have taken place in grocery retailing in the past 20 years; and (2) to evaluate the implications of these structural changes for market performance. They have succeeded admirably in the first objective, but not, in the reviewer's opinion, in their second because the fundamental hypotheses of structural analysis are incorrect.

The first four chapters of this book provide a good summation of the relevant data with respect to the number, size and type of grocery stores; trends in the sales and percentages of total grocery business of the leading corporate chain systems; and an especially good section dealing with the merger movement of recent years among retail food firms. Chapters five and six have some new and useful data regarding vertical integration by the chains with some perceptive comment regarding the causes and results of this tendency. This book gives the best summary available of economic trends in the grocery business, and it should be read not only by marketing students but by everyone interested in what is happening in the food industries.

It is when the authors begin trying in the latter chapters of the book to relate economic performance to market structure that they run into difficulty, for this is a hopeless undertaking more likely to lead to error than to understanding. Essentially the structuralists are in the rigid tradition of 18th century classical economics, the basic error of which is the assumption that atomistic economic structures will result in maximum output at lowest prices. This assumption simply does not apply to a modern economy.

Because grocery stores are becoming larger in size and smaller in number (with an increasing percentage of sales concentrated in the larger stores), the authors say that the structure of local markets in food retailing approximates the oligopoly model, from which they conclude that the situation is less competitive and market performance thereby worsened, as compared with earlier times. As a result of mergers and increases in relative size among most of the leading corporate chains (excluding several of the largest ones, which have not increased their share of total market in recent decades), their conclusion is that we might expect the emergence of a "live-and-let-live" policy among these chains.

Actually, competition among food retailers is sharper and more effective today than it was 40 or 50 years ago when grocery retailing approximated the atomistic model idealized by the structuralists. The chief

reason why the tempo and effectiveness of competition in grocery retailing has been stepped up is the great progress made by the affiliated independents in matching the efficiency and merchandising skills of the corporates. The importance of this development as a competitive factor seems to have been largely ignored in this book.

The discussion of vertical integration by the grocery chains is on the whole very good. But here again, the authors seem to have been more hindered than helped by the paraphernalia of their market structure analysis.

Their first hypothesis regarding retailer integration into food manufacturing is that such integration is to be explained largely by the market structure of the industries supplying the retailers—specifically retailers will be most likely to integrate into those manufacturing areas characterized by a relatively high degree of concentration of control. Now this is a very complicated matter which cannot be explained in terms of market structure analysis. But if one were to insist on using this methodology, an opposite hypothesis probably would be more nearly correct—i.e. retailers will tend to integrate into manufacturing areas where there is relative ease of entrance, and such areas are *not* likely to be characterized by a high degree of concentration of control.

In another facet of their discussion of vertical integration, the authors arrive at a correct conclusion, but thereby do violence to one of the precepts of structural analysis. They point out that vertical integration by grocery retailers has added a new and effective dimension of competition for the food manufacturers, which, indeed, it has. But vertical integration (as they correctly point out) is a concomitant of large-scale organization, which represents a structural departure from the atomistic model.

In their concluding comments, the authors list three criteria of industrial performance: (1) a decreasing ratio of profits as a percentage of sales, which they cite as an indication that the food industries are performing in a more satisfactory manner than in pre-war years; (2) an increasing ratio of advertising expenditures to sales, which they regard as in part a social waste of resources; and (3) the relatively small expenditures by the food industries for technical research (as compared with advertising expenditures), which they deplore and associate with changes in market structure.

Now these matters are not as simple as the authors make them out to be and their ramifications cannot be analyzed in terms of market structure. There is a great to-do these days about stepping up the rate of growth in our economy. Since growth is to a considerable extent financed out of profits, one can plausibly argue from this standpoint that the public interest would be served better if industrial profits were higher.

As for advertising expenditures being a social waste, it needs to be

remembered that they go in large part to provide financial support for our media of communication and entertainment (newspapers, magazines, radio and TV). The alternative to supporting these media from private enterprise funds is to do it under the aegis and support of government, and the pros and cons of this take us deep into the ideological woods.

Quite probably the authors are right that the public would be better off if more money were spent for technical research by all branches of industry. But the funds presently devoted to this purpose come mainly from the larger companies, which represent a departure from the atomistic market structure favored by the authors.

The simplest and most direct measure of industrial performance by the food industries is, of course, a comparison of today's super-market with the old-fashioned grocery store—the costs, margins, variety, palatability and convenience of the foods found in both—but this criterion is not examined by the authors.

What is said here in derogation of market structure analysis should not be taken to mean that this is not a good and worthwhile piece of work, because in most respects it is. Professor Mueller is among the most seasoned and perceptive agricultural economists working in this general field. One could wish, however, that he would throw away some of his old-fashioned analytical tools and make a more pragmatic and less doctrinaire approach to modern economic problems.

A. C. HOFFMAN

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Modern Land Policy, Papers of the Land Economics Institute, University of Illinois. Urbana, Ill.: University of Illinois Press, 1960. Pp. x, 449. $8.50.

The Land Economics Institute was held at the University of Illinois during the eight-week summer session of 1958. This volume is composed of 32 papers prepared either for delivery at the Institute or as formal statements of subject matter covered in seminar sessions.

The 32 papers are grouped in four parts: Potentials in Land Resources and Demand, Impact on Land Use of Specific Demands and Resource Programs, Planning and Programming Land Resources Policy, and Land Use and Tenure Problems. The 33 authors are well known in the field of resource economics and resource planning and include four authors from outside the United States.

Because it is a collection of 32 papers by different authors, it is impossible to say more about the book as a whole than that the papers are well written and scholarly, and that the binding and printing are excellent and attractive. Most of the papers were prepared for delivery to the students who were registered in the Institute. For this reason, most of them are

(and read like) informative lectures to graduate students. Only a few of them probe outward into new areas of theory and fact relative to resource economics analysis and policy. Because they were prepared for presentation in a "class room" setting, most of the papers are admirably adapted to use as assigned readings at both the undergraduate and graduate levels in courses in resource economics and policy.

It is manifestly impossible to review each of the 32 papers and one runs considerable risk in making mention of a few and not the others. The biases of the reviewer will show up here, but some of the papers deserve mention by reason of their probing outside the confines of the familiar.

Dr. Ciriacy-Wantrup's paper, "Conceptual Problems in Projecting the Demand for Land and Water," is the scholarly product we usually receive from his pen. As the title implies, he is here concerned with probing the economic concept of demand as it pertains to land and water and, particularly, the problems inherent in projecting or predicting future demands as a base for policy and program decision making.

Dr. Tolley's paper, "Interrelated Land Development Possibilities," is an ingenious and intriguing effort toward "predictions of output where demand and supply [of land resources] do not increase at just the same rate. In contrast to usual projections, prices and rates of substitution among factors are included in the analysis. A model is developed that can be solved in terms of the demand for and supply of agricultural land. The model is used to make a twenty-year projection." It is well worth reading.

The paper, "Appraisal of Federal Investment in Water Resources," by Dr. Renshaw is an excellent one-chapter statement of the complexities of "benefits-costs" analysis in public investment decision making in the water resource field. He applies his reasoning to such analyses as made by the Bureau of Reclamation relative to Reclamation projects. The latter analyses don't show up very well under his scrutiny.

One of the extremely well-written papers, both in terms of what it has to say and how it says it, is Dr. Charles Hardin's "Political Planning: Possibilities, Limitations, and Aberrations." I recommend it heartily to any reader interested in government planning and programming in the modern world whether he is "for or against" it. Hardin's paper is thought-provoking. "The United States must develop an effective planning function. . . . To fulfill this need requires a basic integration of political power which, in turn, may raise the eternal question of the control of power in a form that is new for us: how to keep the emergent political planning function in hand. . . . Our most urgent political danger . . . arises . . . from our inability to provide a political base necessary for a strong, but accountable, planning function."

Dr. Charles Stewart was one of the imaginative thinkers and writers

on farm policy problems in the pre-New Deal period, when our grasp of the issues and adept handling of the analytical tools concerning policy were as immature as our approach to an economic understanding of resources policy is today. He was ahead of his time then, and in his paper for this volume, "Flexibility in Land Tenure for Family Farming," he is away out ahead of the multitude (or just "way out") again. His proposal is that the government recapture (thro' purchase) all titles to farm land, county by county, over a span of 50 years. As these titles come into its hands, it is to reshape and resize farms, replan them for conservation, replace and relocate structures, and repatent titles. Within a year of taking possession, the government will sell to private farm operator families 50-year lease holds with no down payment. All farm land would thus go through this reshaping and repatenting process once in each half century.

The papers by Dr. Parsons, "The Place of Land Reform in a Developmental Agricultural Policy," and Dr. Raup, "Land Tenure Adjustments in Industrial-Agricultural Economics," are penetrating studies of these topics. Both will bear careful reading.

The paper by Dr. Clawson, "Land Use and Demand for Land in the United States," is a digest of the book he wrote with Burnell Held and Charles Stoddard, *Land for the Future*. The paper by Dr. Schultz, "Land in Economic Growth," is a restatement of a thesis he has explored in several writings to which he refers in a footnote and to which he might have added his article in the *Journal of Farm Economics* (XXXIII, 2, May, 1951) "A Framework for Land Economics—The Long View."

The nine papers in Part II explore the impacts on land use of many increasing demands for land such as urban and urban-related uses, highway improvement, recreation, timber, and water.

Part IV contains seven papers that consider land use and tenure problems in the United States, the Great Plains of the United States, western Canada, western Europe, Great Britain, southern Italy, and India.

This is a book that all resource-oriented economists should be familiar with and should have on their reference shelves. If they are teachers of the subject, they should consider using it extensively for class assignments.

M. M. KELSO

University of Arizona

Adjustments in Agriculture—A National Basebook, Mervin G. Smith, Director, Carlton F. Christian, Editor. Ames: The Iowa State University Press, 1961. Pp. xvii, 376. $3.95.

The major premises of this book are well known to agricultural economists. United States agriculture is pictured as in a stage of rapid development. Chronic rather than temporary overproduction, or a continuing market disequilibrium, is generally assumed. Nine of the 13 chapters

are primarily concerned with this topic. The need is clearly recognized for adjusting agriculture to fewer farms, increases in capital structure per farm, and reduced labor requirements per farm and in total. The family farm is held as a desirable goal.

The last four chapters discuss the need for adjustments in human resources to balance farm population with the reduced labor requirements in agriculture. Improvements in community facilities are required to increase the levels of living in rural areas. Government programs and education, designed to facilitate greater labor mobility, are crucial in the total effort of agricultural adjustment. A price-support program for some commodities is accepted, but no general or firm position is taken on comprehensive price and production-control programs.

The book is written by 19 of the leading agricultural economists of this country with each chapter under separate authorship. The intended audience includes teachers, research and extension workers in colleges and universities, farm leaders and organizations, political leaders, agricultural businessmen, government agencies, and all others interested in the role of agriculture in development. The publication was planned by a steering committee of agricultural economists, assembled and published under the sponsorship of the National Committee on Agricultural Policy, the Farm Fcundation, and the Center for Agricultural and Economic Adjustments at Iowa State University.

The book presents considerable information which can be useful as background in agricultural planning and adjustment programs. However, far too much attention and repetition exist in the discussion of over-all trends and in emphasis on surpluses and short-run inelasticity in supply and demand. More important, some really vital and important questions are either treated very lightly or ignored completely. Some of the more important of these worth noting are the following:

There is little in this book on the great need for economic development and alleviation of hunger and malnutrition in other countries of the world and how this situation conditions relevant alternatives in our national policies, including international trade.

No mention is made of the case for strategic stockpiles of food or for a national food cache which may be absolutely vital for survival in event of nuclear war. The failure of economists to give this contingency adequate recognition in policy and programs can prove to be the great oversight of current policy.

Considerably more discussion would be helpful on alternative development opportunities in communities where low-income farms are located.

The book could have been more useful to the intended audience if less space had been given to discussion of supply and demand and more material had been presented on the possible accomplishments in adjustment

through national programs, state and local action, by individuals, credit institutions and private businesses.

There are a few conclusions that are questionable in light of available evidence. Agricultural production is more responsive to economic incentives than is generally imputed. Consumption levels are probably more variable than the emphasis on inelasticity of demand indicates. These weaknesses are the exception rather than the rule.

Although little new knowledge is presented and a major part of the policy emphasis is misplaced, the book is well written and will be useful to many people as a general reference or background for viewing some of the economic problems of agriculture.

HAROLD G. HALCROW

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Agricultural Production Functions, E. O. Heady and J. L. Dillon. Ames: Iowa State University Press, 1961. Pp. viii, 667. $6.95.

Economic concepts, research, research methodologies and applications of physical and firm production functions are discussed in this voluminous book. The work is intended to interest agricultural scientists with particular appeal to those interested in integrating physical, biological and economic disciplines in research efforts. Continued growth in farm size and agricultural technology increases the number and complexity of resource efficiency problems and suggests the desirability of further integration of disciplines.

There are three basic sections in the text. Chapters 1 through 7 review production function concepts and the procedures and problems involved in production function estimation. A second section includes studies of empirical physical production functions that have been completed and reported on from Iowa State University over the past ten years. The final section, on farm firm production functions, includes an interesting collation and analysis of such studies from throughout the world.

Section I performs the useful purpose of assembling in an orderly manner discussions on forms, specification, data collection, data analysis and empirical problems in production function research. These ideas are prefaced with a concise chapter dealing with the usefulness and need for production function research as well as a brief historical summary. The material in this section is not new but it has been assembled in sufficient detail to serve as a useful reference. These chapters should serve as the core of graduate student-staff seminars involving interested disciplines. Perhaps Dr. Heady's success in stimulating and organizing interdisciplinary research efforts can be extended with the thoughtful use of these materials.

Section II presents research results for six products. Economic optima are identified for alternate levels of technology and sets of relative prices.

Suggestions on the presentation of results from such research are given in the use of price maps and cost calculators. However, progress in the separate step concerned with communicating the results of research dealing with economic optima has not kept pace with the progress in research methodology.

The discussion of farm-firm production functions in section III is quite extensive, since the weaknesses of such functions and the availability of alternate methodologies limit the usefulness of such functions. Problems of resource efficiency in underdeveloped countries may be oriented more toward research on new technologies than toward research on resource reorganization. The "average technology" limitation of firm production studies, their limited use in individual firm decisions, and the difficulties of drawing other than extremely broad inferences about intraregional and interregional resource transfers leads one to question the extension of such studies.

This book may be used by agricultural economists in intermediate and advanced production economics courses. However, its primary value should be to cultivate interdisciplinary research activities and to stimulate the interests and increase the knowledge of agricultural scientists other than agricultural economists.

A. J. COUTU

North Carolina State College

Marketing of Agricultural Products, Richard L. Kohls. New York: The Macmillan Company, 1961. Pp. xiv, 424. $7.50.

This is the second edition of Dr. Kohls' book. The previous edition was published in 1955. The purpose of the book is to provide starting points for students of agricultural marketing. It is designed for students with some background in elementary economics as well as students who have had no contact with economics. It is primarily a description of the marketing system. Dr. Kohls divides the book into the following headings:

Part 1: The Framework of the Marketing Problem. This section contains the definition and scope of marketing. It includes a brief description of the consumer market for agricultural products and the nature of the production unit in agriculture.

Part 2: Some Functional Problems. This includes price determination, the role of prices, demand, supply and cyclical and seasonal price variations. The role of government, agricultural pricing programs, demand expansion and the traditional functions of marketing are also discussed.

Part 3: Commodity Marketing and Problems. This section includes a description of livestock, dairy, poultry and egg, grain, cotton and tobacco marketing. The place and problems of agricultural cooperatives and the role of government in agricultural marketing are also discussed.

In short, the book attempts to describe the nature of the entire agricul-

tural marketing sector of our economy to the beginning student of agriculture in a simple and understandable fashion. The author's objective is indeed worthy. Problems of marketing should be presented to the student in as simple a manner as possible and in such a way that they will result in a greater understanding of the nature and complexity of the marketing system. In pursuing this objective, this reviewer had the feeling that sometimes the language used to describe the different sectors of the market was imprecise and misleading. In several instances the understanding might have been increased by the use of more precise language. In one case the word "pushed" was used to indicate active participation in the construction of transportation systems by governmental units. In this instance a statement to the effect that various governmental units have subsidized highway and airway transport systems as a method of encouraging the development of these transportation methods would have given the reader a clearer picture of the role of various governmental units in the development of transportation.

In striving for brevity and simplicity in many areas, the author has oversimplified to the extent that in several cases the reader is left with an erroneous impression as to the nature of the problem or the possible solutions. On page 12 the author suggests that the improvements in the domestic marketing system which occurred during the 1920's effectively solved the surplus problems of that time. While improvements in marketing undoubtedly contributed to the efficiency of the entire agricultural economy they did not solve surplus problems. Another oversimplification occurs on page 154 where the author states, "In manufacturing there are few enough firms in each industry so that a considerable oligopoly element exists. Each firm, conscious of the effect of its own production on price, reduces production as demand declines." This is an extreme oversimplification of the nature and structure of the manufacturing sector and leaves an erroneous impression as to how the manufacturing sector operates in production, pricing and marketing.

In addition to the oversimplification problem cited above, the book does not have an adequate treatment of the nature and importance of foreign markets and the relationship of foreign markets to domestic markets. The author states that the foreign markets are very important to the health and well-being of the agricultural economy of the United States; however, after this statement only a few pages are used to dispose of the entire area of foreign trade in agricultural products.

The treatment of government programs in agriculture and their relationship to marketing problems is very superficial. It is primarily a description of the history of government programs but includes no material concerning the current programs and what impact they may have on marketing.

Many of the above criticisms are matters of interpretation or represent different viewpoints among individuals. However, in several instances statements are included which are technically incorrect. On page 120 the author states, "If the law of demand is valid, the demand curve will always slope downward and to the right on a graph similar to Figure 1," On page 121 a similar statement is made concerning supply: "If the law of supply is valid, the supply curve will always slope upward and to the right on a graph which is similar to Figure 2." While both of these statements are the usual case, they are not technically correct. Even though this book is intended for beginning students who would not be interested in the exposition of the backward sloping supply or demand curves, the fact that they exist must be recognized.

In the same section, on page 133, the author states, "From this it can be seen that, in the long run, adjustments will be made which will tend to lower prices if they have been above costs and raise prices if they have been below costs. A perfect equilibrium price in the long run would be that which would encourage neither expansion nor contraction in the production." This statement is correct if the economy is static. An equilibrium price in a dynamic economy would account for changes in demand, changes in technology and institutional changes over time. This may result in either some expansion or contraction of production but the price would still remain in equilibrium. Here again I feel that the oversimplification may very easily result in students obtaining misconceptions as to the nature and problems of marketing.

One final technical point. On page 303 the author makes the following statement, "The increasing demand for the other dairy products, which has come about through population growth, rising standards of living and an increased consciousness of the value of milk as food, has meant that an ever increasing portion of the total milk supply is needed to fulfill these demands. Less has been left for butter manufacture, and into this gap have stepped the spreads manufactured largely from vegetable oils." This is a rather novel explanation of the decline in butter consumption. It completely ignores the relative prices existing among butter and butter substitutes. It also assumes that the supply curve for butter approaches perfect inelasticity. If this were actually the case it is difficult to see why the government, through CCC operations, would have purchased and stored the large quantities of butter it held during the 1950's. If the shift in butter consumption was largely the result of supply phenomena, storage stocks should have been zero, government carryover should have been zero and prices should have risen to compensate for the lower available supply. This was not what occurred. This is not an adequate explanation of the shift in butter consumption and will only lead to further misconceptions on the part of students.

In conclusion, the reviewer feels that the book would have better served the objectives of the author if more emphasis had been placed on the economic principles involved in the marketing process and less space had been devoted to a description of the commodity marketing channels. With a better foundation in principles, students would be in a better position to recognize and understand the marketing problems existing in the different commodities.

Also, teachers using this book should consider using additional supplemental readings to provide a greater exposure to the economic principles underlying the marketing process.

LEE KOLMER

Iowa State University

Western Forest Industry, An Economic Outlook, John A. Guthrie and George R. Armstrong. Baltimore: Johns Hopkins Press, 1961. Pp. ix, 324. $6.50.

Guthrie and Armstrong have added an interesting, clearly written, and useful work to the growing number of analytical endeavors in forest economics. The approach taken is regional and makes much good sense. However, the authors are careful to bring in important interregional relations and comparisons wherever relevant. The study's first objective is to describe the principle forest industries (lumber, pulp and paper, and veneer and plywood) of the Pacific Slope. This is a vast region encompassing the 11 western states and Alaska and also includes British Columbia. This region also contains some 3 trillion board feet of standing timber, including over one-half of all the sawtimber and more than two-thirds of all softwood sawtimber in North America. Lumber and softwood plywood production is concentrated here, and pulp and paper manufacture is becoming increasingly important.

The study has for another objective a fairly detailed examination of current conditions and past trends within the several forest industries and of the forest resource upon which these are based. Given some general assumptions about future regional and national economic conditions, the authors proceed to projections of forest products consumption. Of considerable interest is an attempt to indicate probable changes in structure and shifts in location of the forest industries of the Pacific Slope in the light of the projections. Also discussed are the major forestry policy issues which will have to be considered by industry, government, and other groups concerned with the future of forestry in the West. The authors work logically from the premise that what happens on the Pacific Slope will greatly influence the forest economy of the nation.

By 1975, it is expected that the West will be even more important in lumber production than it is today. The authors also anticipate a rapid

increase in the consumption of pulp and paper by 1975, a more rapid increase than has been projected by either the Stanford Research Institute study (*America's Demand for Wood 1929-1975*) or the Forest Service study (*Timber Resources for America's Future*). With respect to future softwood plywood consumption for the nation, virtually all is expected to be produced on the Pacific Slope.

In making projections of consumption, two methods were considered, one employing regression and the other relying on visual extrapolation of the historical data. The nonmathematical method was relied upon more heavily, presumably because it provides more flexibility in modifying past trends according to assumptions concerning expected future changes. Actually, in view of the importance attached to the projections, it is somewhat surprising that more attention was not given the methodology of projection. The notion that mathematical projections are inflexible is probably not completely valid when more sophisticated techniques are considered. It is possible to develop more realistic economic structures using recently developed statistical and econometric procedures which will allow for coefficient modification in the light of expected changes and still provide for much more realistic projection.

Despite a lack of sophistication in projection technique, it is difficult to argue against the numbers used in the study. In the opinion of the authors, there does not seem to be any serious question about the capacity of western states to meet forest industry needs in 1975, provided certain major timber harvesting problems are worked out. The most important policy problems result from anticipated cutting of timber to meet industrial requirements between now and 1975 and involve a prospective imbalance of timber supplies as between public and private forest lands. Forest industry argues that private lands of the Pacific Slope which now bear cutover stands of timber can supply a reasonable share of the needed future supply if given a chance to mature. In order that these industries maintain themselves in the interval, there has to be more cutting on federal lands (primarily National Forest timber).

Chapter 5 discusses how the U.S. Forest Service, the principal administrator of these lands, under a policy of multiple use and sustained yield might be guided in adjusting allowable timber cut to best approach maximization of net social revenue in general during the interval. The authors reason that not only would multiple use management of forests protect the nonmarket as well as market values produced by the forest, but that sustained yield practiced along with it will help do away with the social and private costs associated with forest industry abandonment and migration based on other than sustained yield systems. They strongly intimate that maximization of net social revenue, if not reached, would seem to be more nearly approached under sustained yield management.

For purposes of discussion, sustained yield management is quite closely defined as follows:

> Sustained yield management is that form of timber management which through application of today's economically feasible cultural measures on a tract of forest land of such size that it can support a stable (nonmoving) plant or plants in perpetuity, provides for the following: (a) complete utilization of the timber growth capacity of the land; (b) a balance of tree size or age classes that will provide an annual supply of merchantable-size timber equivalent to the total annual growth capacity of the land; and (c) an annual harvest of merchantable timber equivalent to the total annual growth on the land.

Although sustained yield is usually not so well defined, the principles expounded here are fairly widely held. In this particular case there is an attempt to wed some economics to what amounts essentially to physical sustained yield of timber and other forest products. The blend is not entirely successful, as the authors point out later, and it might actually be somewhat misleading. It would be surprising if maximization of net social revenue (surely a worthy concept, but one which poses tremendous operational difficulties) could be easily approached within the stringent restrictions of the definition, especially Parts (a) and (c). Foresters as a group have been too long bound by the physical restrictions embodied in the notion of sustained yield. Maximization of net revenues, whether individual or social, may very well call for a harvesting program which does not remain stable or aim toward complete utilization of the productive capacity of a timber tract. Indeed, if net revenues are to be maximized over time, it may be that cutting (and growth) must be varied in accordance with projected or anticipated changes in demand and supply of the products made from timber, insofar as this procedure can be followed within a complex productive plant like the growing forest.

Chapter 5 also contains a very interesting and thought-provoking discussion of the several suggested criteria which might be used to regulate the allowable cut of mature timber on public lands until such time as presently immature private timber can be placed on sustained yield. Of the several criteria suggested, the authors appear to favor fluctuating timber and timber product prices as the most usable. They point out that if the allowable cut of public timber were increased when stumpage prices were rising, the effect would be to bring prices down; if prices tended to rise relative to prices in general, the allowable cut could be increased. Here, as elsewhere in the study, considerable emphasis is given stumpage price and supposedly its tendency to rise indefinitely. It does not necessarily follow that stumpage prices will continue to climb rapidly or indefinitely. The value allocated to stumpage is still only a residual. The authors seem to make stumpage price more of a causative factor in forest product price formation than it actually is.

The book is a welcome addition to the field of applied forest economics, Despite some lack of analytical sophistication, students and foresters, especially those who work on the Pacific Slope, should find *Western Forest Industry* a very useful reference volume.

Last, but by no means least, a very useful and apparently new forest type map of the forested areas of the Pacific Slope is included as a separate sheet conveniently carried in a pocket at the end of the volume.

I. IRVING HOLLAND

University of Illinois

Social Statistics, Hubert M. Blalock, Jr., New York: McGraw-Hill Book Co., 1960. Pp. xiv, 465. $7.50.

One of the McGraw-Hill series in Sociology, this book was "written primarily for those students of sociology, both advanced undergraduates and graduate students, who actually intend to engage in social research." Subject matter has been divided into three parts. Part I consists of two introductory chapters. Part II, of five chapters, covers the field of descriptive statistics in about sixty pages. The main part of the text, Part III, consisting of sixteen chapters, is devoted to inductive statistics. It describes the logic of testing hypotheses, and the probabilistic basis for conclusions about them, and illustrates the procedure with an application of the binomial. This is followed by chapters covering single and two-sample tests of means and proportions and point and interval estimation. Succeeding chapters are devoted to two-sample nonparametric tests, contingency problems, analysis of variance, correlation and regression (both simple and multiple), covariance techniques, factor analysis and other multivariate techniques and finally sampling procedures. A short concluding chapter includes some reflective comments on overall strategy in selecting techniques of analysis. The first of two appendices includes a brief review of algebraic operations; the second contains the usual statistical tables.

This is a well-written book. The author has a clear, easy-to-read style. The presentation is orderly and to the point, with few slips. Although the examples are drawn from sociology, the analogies are close enough that both students and professional workers in agricultural economics would benefit by reading this book. Several points are worth noting in this connection.

1. The author is meticulous in his adherence to the notion of "statistical conscience" in developing and testing hypotheses and drawing conclusions. All too often, some workers violate good research procedures by slipshod statement of hypotheses or choice of test procedures and criteria after data has been collected and perhaps even summarized. If the regimen presented by Blalock were followed, it should help to improve the

quality of research. The generally clear statement of assumptions underlying each of the tests described should lead users to be better aware of the limitations of generalizations based on use of such tests.

2. The author has done a nice job of integrating the underlying logic of analysis of variance and correlation procedures including applications to nominal and ordinally scaled data. Too often these techniques are so compartmentalized that their interrelations are not appreciated by the student. Their essential unity is brought to bear in a clearly written chapter on analysis of covariance, a technique which, I believe, agricultural economists have not made sufficient use of.

3. Since the author had to draw the line somewhere on material to be included, he has been quite careful to give the student specific reference to more advanced treatments of some problems, particularly those which involve specialized applications.

Perhaps the weakest part of the text is the section on sampling. One might expect that a text designed for those "who actually intend to engage in social research" would devote more attention to the planning and conduct of social surveys, particularly their sampling aspects. This chapter is included almost as an afterthought, and the graduate student who is beginning his first research project will find little more than generalizations to help him come to grips with the practical problems of survey or experimental design and data collection.

While this text is designed to "enable students with limited mathematical background to understand the fundamental ideas of statistical inference," and does a good job of meeting this objective, we may soon expect most students to have a better mathematical background than this book presupposes. Progressive upgrading of our demands on students is necessary or we will be selling them short. When I note my daughter, a ninth grade student, working on sets and problems in linear progamming as a part of the regular mathematics program, it seems obvious that soon we can be less solicitous of the student with limited mathematical background.

Many statistical subjects of interest to agricultural economists are, of course, not discussed in this book. Consequently it probably will see only limited adoption by the profession as a text. Nevertheless, for agricultural economists as well as sociologists with limited mathematical background this book can be recommended for its usually lucid discussion, particularly of the testing of hypotheses.

HARLOW W. HALVORSON

University of Wisconsin

GARNET WOLSEY FORSTER, 1887-1961

GARNET W. FORSTER, Professor Emeritus of North Carolina State College, died in Raleigh on October 21, 1961. Dr. Forster was a pioneer in Agricultural Economics and exerted a great influence in this field. He received his B.S. degree in 1914 from Cornell, his M.S. in 1917 and Ph.D. in 1923 from the University of Wisconsin. He served with distinction in World War I. He was appointed Professor of Agricultural Economics at the University of Kentucky in 1920, then became Assistant Chief and later Acting Chief in the Office of Farm Management, USDA.

Dr. Forster went to North Carolina State College in 1923 as Head of the Department of Agricultural Economics, a position which he held until 1950. During this period he conducted wide programs of research and teaching with energy and enthusiasm. His views and ideas, presented in numerous books, articles, bulletins, reports, and talks, both added to the basic knowledge and practical application of farm economics and opened new vistas of opportunity for the many students who studied under him. He was admired and respected by colleagues and students alike. His keen sense of humor never clouded the seriousness with which he approached every problem that confronted him.

In 1957 Dr. Forster was elected a Fellow of the American Farm Economic Association, a befitting honor in recognition of the distinguished service which he had rendered. Upon his retirement from academic life in 1953 he contributed his personal library of books, journals and publications to the Agricultural Economics Department of North Carolina State College, where they were used as a nucleus to establish a Departmental Library in his honor.

He is survived by his wife, two daughters and three grandchildren.

OBITUARY

V. JOHN BRENSIKE, Head of the Grains and Feeds Section, Marketing Economics Division, ERS, died suddenly on July 16, 1961. He was employed in the Wisconsin PMA Office from 1941 to 1947. Following service as a Naval Reserve officer during World War II, he did graduate work at the University of Wisconsin and received the Ph.D. in 1949. He was employed in the Department of Agriculture at Washington from 1948 until his death. Dr. Brensike was the author of several research bulletins. In 1960 he was the chairman of the U.S. Scientific Exchange Team in grain handling, storage, and processing that visited Russia.

IMOGENE BRIGHT, an agricultural economist in the Division of Marketing Economics, ERS, died suddenly on June 12. Miss Bright graduated from the University of Indiana in 1945 and received an M.A. degree in economics from The American University in 1955. She was working on a Ph.D. dissertation to be submitted to the American University, where she had completed all other requirements. Miss Bright was employed in the Department of Labor from 1945 to 1948 and from 1951 to 1955, and in the Department of Agriculture from 1948 to 1951 and from 1955 until her death. She was the author of many research reports.

HOWARD G. FREY, of the Lincoln, Nebr., staff of the Agricultural Estimates Division, Statistical Reporting Service, died on June 6 from injuries received in an automobile accident the day before.

NEWS NOTES

W. J. ANDERSON, of the University of British Columbia, has been appointed to the staff of the Scientific Research and Development Project of the Royal Commission on Government Organization, Ottawa.

ADLAI ARNOLD has returned to the University of Arkansas after completing the residence requirements for the Ph.D. at Oklahoma State University.

RAYMOND A. BAILEY, Ohio State University, was promoted to Associate Professor July 1.

MAURICE E. BAKER, Ohio State University, has been appointed Assistant Professor and Technical Leader for an ICA special training course in marketing of agricultural products held at the University during the Autumn Quarter.

WALLACE BARR, Ohio State University, was promoted to Assistant Professor July 1.

ELMER F. BAUMER, Ohio State University, was promoted to Professor July 1.

R. JAMES BECKER is on leave from Pennsylvania State University to serve with ICA in Surinam.

R. W. BLAKE has been appointed Canadian Trade Commissioner at Kingston, Jamaica, W.I.

JOHN C. BLUM has been appointed director of the Dairy Division, Agricultural Marketing Service, USDA.

C. A. BONNEN, Professor of Agricultural Economics at the Agricultural and Mechanical College of Texas, retired August 31. He had been in the Department for thirty-four years.

VICTOR V. BOWMAN, Marketing Economics Division, ERS, retired June 30. He was employed in the USDA for many years and also was with the ICA as a marketing specialist in several countries.

HAROLD F. BREIMYER, formerly on the staff of the President's Council of Economic Advisers, has been appointed Economist, Office of Administrator, Agricultural Marketing Service.

R. G. BRESSLER, JR., has returned to Berkeley from a year's leave to participate in the Program of the Center of Specialization and Research in Agricultural Economics for the Mediterranean countries that is being conducted at the University of Naples with the support of the Italian Government, the Ford Foundation, and the University of California.

CARROLL BRUNTHAVER resigned from Michigan State University September 1 to assume his new position as Research Director with the Grain and Feed Dealers National Association.

JOHN S. BUCHE, Agricultural Estimates Division, Statistical Reporting Service, stationed at Iowa, resigned in June.

W D. BUDDEMEIER, Professor of Farm Management, University of Illinois, has accepted a second two-year assignment as farm management adviser at the Government Agricultural College at Kanpur, U. P., India. He will continue to serve as group leader for the Illinois agricultural participants in the ICA program.

F. RICHARD BURKE, Agricultural Marketing Service, USDA, has been named Acting Deputy Administrator for Regulatory Programs, with supervision of commodity procurement.

W. T. BUTZ, Pennsylvania State University, is on leave until March 24 to work with the Marketing Economics Division of ERS.

HARVEY W. CALDWELL has been appointed Head of the Department of Extension Education of the Ontario Agricultural College, Guelph.

R. H. CAMPBELL has been appointed acting chief of the Special Projects Section of the Agricultural Division of the Dominion Bureau of Statistics, Ottawa.

GEORGE L. CAPEL was named in charge of Extension Marketing in the Department of Agricultural Economics at North Carolina State College in September. He was formerly with USDA in Gainesville, Florida.

THOMAS F. CARROLL has accepted a post with the Inter-American Development Bank in Washington. He will be in charge of the agricultural economics aspects of the Bank's work with special reference to the social development fund under the Act of Bogotá.

ROBERT L. CARTER was appointed Assistant Agricultural Economist, University of Tennessee Agricultural Extension Service, on August 1.

JAMES P. CAVIN has been designated Deputy Director of the Economic and Statistical Analysis Division of the Economic Research Service.

J. W. CHANNON, formerly with the Royal Commission on Transportation, Ottawa, has transferred to the Grains Division of the Canada Department of Agriculture, Ottawa.

BOB CHERRY, Extension Economist, Agricultural and Mechanical College of Texas, is on study leave for the current academic year at North Carolina State College, working on a Ph.D. in the Agricultural Policy Institute.

WAVERLY T. CHUMNEY, formerly with the Farm Economics Division, Economic Research Service, resigned in June to enter private business in Blacksburg, Va.

CHARLES L. CLELAND, Department of Agricultural Economics and Rural Sociology, University of Tennessee, has been promoted to Associate Professor.

LYNDON U. COCKROFT has resigned as Assistant Professor at the University of Arizona to take a position with the Economic Research Service, USDA.

NORMAN R. COLLINS is on leave from the University of California to participate in the Program of Specialization and Research in Agricultural Economics at the University of Naples.

NEIL COOK has been appointed Agricultural Economist with the Land & Water Branch of the Farm Economics Division, ERS, stationed at Stillwater, Okla. He will do research in the area of Water Economics and pursue graduate work at Oklahoma State.

C. RICHARD CREEK, formerly of the Colorado State University, has joined the staff of the Marketing Economics Division, ERS. He is stationed in Hawaii, where he will conduct research on market development for coffee and other specialty products.

ARTHUR B. DAUGHERTY joined the Atlanta, Ga., staff of the Farm Economics Division, Economic Research Service, in June.

FRANK M. DEFRIESE, Associate Agricultural Economist, University of Tennessee Agricultural Extension Service, has been granted leave for the current academic year for study at the Agricultural Policy Institute, North Carolina State College.

ARTHUR DOMIKE, Associate Professor at the University of Rhode Island, joined the Basic Research Group, Marketing Economics Division, ERS, for a year beginning September 15. He received the Ph.D. at the University of Wisconsin in June.

JOHN L. DREW has been appointed Farm Management Specialist with the Saskatchewan Department of Agriculture.

LOUIS DUCOFF has been appointed Assistant for Farm Population and Rural Development to the Director of the Economic and Statistical Analysis Division of the Economic Research Service.

WALLACE C. DUNHAM, formerly with the Ohio Extension Service, joined the Department of Agricultural Economics at the University of New Hampshire as Retailer and Consumer-Marketing Education Specialist.

HELEN C. FARNSWORTH of the Food Research Institute, Stanford University, presented a paper, "Defects, Uses and Abuses of National Food Supply and Consumption Data," at the Thirty-third session of the International Statistical Institute in Paris.

DARREL F. FIENUP has returned to the University of Minnesota after a year with the Marketing Economics Division, USDA, where he studied the impact of federal grading on the market structure and pricing of lamb.

WALTER FISHER has returned to Kansas State University after a year's leave of absence on a John Simon Guggenheim fellowship doing research in mathematical economics at Yale University.

J. W. FITZPATRICK, who has completed the course requirements for a Ph.D. at Purdue University, has returned to his position with the Economics Division of the Canada Department of Agriculture, Ottawa, where he is Head of the Transportation and Storage Unit.

HERBERT L. FOREST, formerly Director of the Dairy Division, Agricultural Marketing Service, USDA, has been made Director of the Milk Marketing Orders Division, Agricultural Stabilization and Conservation Service.

PHILLIPS FOSTER resigned from Michigan State University in August to accept a position as Associate Professor at the University of Maryland. He will teach and do research in international problems relating to agriculture.

HERBERT C. FOWLER, Farm Economics Division, Economic Research Service, retired in June.

CECIL E. FULLER, Department of Agricultural Economics and Rural Sociology, University of Tennessee, has been promoted to Associate Professor.

EARL I. FULLER, of the University of Minnesota, has accepted a position as Assistant Professor, Department of Agricultural and Food Economics, University of Massachusetts.

VARDEN FULLER is on sabbatical leave from the Department of Agricultural Economics, University of California.

R. C. GILSTORF of the Census of Agriculture, Dominion Bureau of Statistics, Ottawa, is presently in Winnipeg supervising the agricultural census for Western Canada.

GEORGE C. GIRARD, formerly with the Economics Division, Canada Department of Agriculture, has been appointed economist with the Economics Service of the Fisheries Department, Ottawa.

CONRAD GISLASON is now with the Canadian Ministry of Agriculture in Caracas, Venezuela.

GEORGE R. GRANGE, former Deputy Director of the Fruit and Vegetable Division, Agricultural Marketing Service, has been appointed Acting Deputy Administrator for Marketing Services.

H. ALBERT GREEN, formerly a graduate student at Purdue University, has accepted a position with the Market Structures and Practices Section, Marketing Economics Division, ERS, USDA.

HARRY GREENBAUM joined the staff of the Economics Department, South Dakota State College, on September 1.

WALLACE R. GREENE resigned in June from the Washington, D.C., staff of the Farm Economics Division, Economic Research Service.

HAROLD C. GRINNELL, until July 1 Dean of the College of Agriculture at the University of New Hampshire, is now Professor of Agricultural Economics.

GORDON HAASE, Economics Division, Canada Department of Agriculture, is advisor to the House of Commons Standing Committee on Agriculture and Colonization re the Enquiry into Prices of Farm Machinery.

FRANK T. HADY, a member of the Gainesville, Fla., staff of the Farm Economics Research Division, Economic Research Service, retired in June.

MILTON C. HALLBERG has been appointed a Research Associate in the Department of Economics and Sociology at Iowa State University.

GRAHAM HALLEWT has accepted a one-year appointment with the Department of Agricultural Economics of the University of Manitoba. He is a staff member of the University of Wales, and until recently was a consultant to the committee studying the implications for the United Kingdom of the European Common Market.

ARNOLD F. HASELEY, formerly on the staff at Purdue University, has accepted a position in the food distribution extension program at Oregon State.

W. E. HAVILAND has been appointed a research economist with the Canadian Pulp and Paper Association in Montreal.

JOSEPH HAVLICEK, formerly with TVA at Knoxville, has accepted a position as Assistant Professor of Agricultural Economics at Purdue University.

F. R. HAYWARD has joined the staff of the Farm Service Division of the Soldier Settlement and Veterans' Land Act Branch of Veterans Affairs Department, Ottawa.

EARL O. HEADY returned to Iowa State University July 1 from a year spent in research on agricultural and economic adjustment at the Center for Advanced Study in the Behavioral Sciences at Stanford University.

A. A. HEIDT is the new Director of Research and Statistical Services of the Saskatchewan Department of Cooperation and Cooperative Development. He was formerly Cooperative Management Advisor and Economist.

RICHARD G. HEIFNER has been appointed a Research Associate in the Department of Economics and Sociology at Iowa State University.

WILLIAM F. HENRY, Chairman of Agricultural Economics at the University of New Hampshire, received an Outstanding Teacher Award from the local A.A.U.P. Chapter.

B. G. HICKS was appointed Assistant Agricultural Economist, University of Tennessee Agricultural Extension Service, on June 16.

PETER HILDEBRAND, Agricultural and Mechanical College of Texas, resigned in August to assume a position with the Colorado State University.

A. EUGENE HILEMAN joined the Extension Farm Management staff in the Department of Agricultural Economics at North Carolina State College in July.

JIMMYE S. HILLMAN became Head of the Department of Agricultural Economics at the University of Arizona on July 1.

WILLIAM HINSON, Agricultural Estimates Division, Statistical Reporting Service, is now statistician-in-charge with the Field Crop Statistics Branch.

SHELBY HOLDER, Marketing Economics Division, ERS, has transferred from Washington, D.C., to the office at Stoneville, Mississippi. He was replaced in Washington by JOSEPH L. GHETTI of the Stoneville office.

HELMER C. HOLJE is on leave from Montana State College as Associate Professor of Agricultural Economics and Associate Agricultural Economist at the University of Nevada. He is replacing GLEN D. FULCHER, who is presently in Paraguay on a two-year leave from Nevada.

S. S. Hoos has returned to the University of California at Berkeley from a year's leave to participate in the Program of the Center of Specialization and Research in Agricultural Economics for the Mediterranean countries at the University of Naples.

DALE M. HOOVER has completed his Ph.D. at the University of Chicago and in July was placed in charge of teaching in the Department of Agricultural Economics at North Carolina State College.

R. L. HUNT, Professor of Agricultural Economics at the Agricultural and Mechanical College of Texas, retired on August 31. He had been in the Department for thirty-four years.

VIRGIL L. HURLBURT has been promoted to Professor in the Department of Economics and Sociology at Iowa State University.

GEORGE D. IRWIN, who recently completed graduate study at Illinois, has joined the staff at Michigan State as an Assistant Professor. He will work in production economics.

TED LEE JONES, who recently completed his Ph.D. at the University of Missouri, has been appointed Assistant Professor of Agricultural Economics at the University of Tennessee.

WILLIAM O. JONES, of the Food Research Institute of Stanford University, is the U.S. member of the Organizing Committee for the First International Conference of Africanists, to be held in 1962. The committee, composed of representatives from six African countries, the United States, the United Kingdom, and the USSR, met in Ibadan, Nigeria, on September 7-8 to make plans for the Conference and select the date and place. He also was elected president of the Western Economic Association at its 36th annual meeting in August.

PAUL JUSTIS, formerly with the Doane Agricultural Service, has joined the Faculty at Louisiana State University as Instructor in Agricultural Economics.

ORVAL G. KERCHNER, Agricultural Economist, Dairy Section, Marketing Economics Division, Economic Research Service, has been temporarily transferred from the University of Minnesota to the University of Illinois, where he will replace S. W. WILLIAMS in working with the North Central Regional Committee on Dairy Marketing Research.

M. B. KIRTLEY has been promoted to the rank of Associate Professor at the University of Illinois.

A. KUBICEK, formerly with the Board of Grain Commissioners of Canada, has been appointed to the Technical Services and Market Research Department of the Canadian Wheat Board in Winnipeg, Manitoba. This is a newly established department which provides technical services for importers and conducts special research programs as to the overseas markets for Canadian Wheat.

G. A. LANE, who has been doing graduate work at the University of Minnesota, has been appointed to the staff of the Economics Division of the Canada Department of Agriculture, Ottawa.

ADLOWE L. LRSON, Oklahoma State University, has been elected Chairman of

the Research and Education Committee of the American Institute of Co-operation.

JOSEPH H. LEACH and JOHN K. BABCOCK have been appointed Agricultural Officers at the head office of the Canadian Imperial Bank of Commerce, Toronto.

GEORGE E. LEE is now a Farm Management Specialist with the Saskatchewan Department of Agriculture, Regina.

DEANE LEE, of the Department of Agricultural and Food Economics of the University of Massachusetts, will be on leave during the coming year to complete his requirements for the Ph.D. at Clark University.

IVAN M. LEE, University of California, is spending his sabbatical at the University of Naples participating in the Program of Specialization and Research in Agricultural Economics at the University of Naples.

ROY W. LENNARTSON, formerly Deputy Administrator for Marketing Services, Agricultural Marketing Service, has been made Associate Administrator to assist in all phases of administration.

CLAYTON P. LIBEAU has returned from a two-year leave in Indonesia to his position as Poultry and Egg Marketing Specialist in the Department of Agricultural Economics at North Carolina State College.

QUENTIN W. LINDSEY has resigned from the Department of Agricultural Economics at North Carolina State College to accept a position with the International Development Service and will be located in Burma.

JOHN Y. LU, formerly with the Operations Research Section of Tidewater Oil Company, was appointed on October 1 as a Senior Economist on the technical staff of the Corporation of Economic and Industrial Research, in Los Angeles.

JOHN C. MACKEY, with the Agricultural Estimates Division, Statistical Reporting Service, in Texas, retired on June 24 after 28 years of "plowing through agricultural statistics. . . ."

T. G. MAJOR, formerly Canadian Commercial Counsellor in Melbourne, Australia, is presently Consul General of Canada in the Philippines and Trade Commissioner to Formosa (Taiwan).

CARL C. MALONE has resigned as Professor of Economics at Iowa State University to remain in India, where he is assisting the Ford Foundation with a program for increasing food production.

D. A. BRUCE MARSHALL, formerly counsellor (agriculture) with the Canadian Embassy in Washington, D.C., is now director of the Agriculture and Fisheries Branch, Department of Trade and Commerce, Ottawa.

JAMES R. MARTIN, of the Farm Economics Division, ERS, has been transferred to Stillwater, Oklahoma. He will do research in the area of Agricultural Adjustment and pursue graduate work in Oklahoma State.

ARTHUR MATSON accepted a position with the Economics Department, South Dakota State College, on September 1.

ARTHUR MAUCH, Michigan State University, is Visiting Professor with the Agricultural Policy Institute at North Carolina State College for the current academic year.

RICHARD C. MAXON has been appointed an Extension Associate in the Department of Economics and Sociology at Iowa State University.

ROBERT MCCAULEY, Agricultural Estimates Division, Statistical Reporting Service, has transferred to Texas as statistician-in-charge.

FRANCIS B. MCCORMICK, Ohio State University, was made Associate Professor and Assistant to the Chairman July 1.

WENDELL MCMILLAN has been promoted to Chief of the Fruit and Vegetable Branch, Marketing Division, of Farmer Cooperative Service.

GEORGE L. MEHREN has been on leave from the University of California for a six-week tour of duty with the International Cooperation Administration Mission in Korea.

JOHN W. MELLOR, of Cornell University, has been appointed Associate Director of the University's Center for International Studies. He will also continue with research and teaching in the economics of agricultural development.

H. J. MESTERN, formerly with the F.A.O. in Rome, has been appointed economist with the Economics Division of the Canada Department of Agriculture, Ottawa.

CHARLES C. MICHEEL, Farm Economics Division, Economic Research Service, formerly stationed at Manhattan, Kansas, is now at Newell, S. Dak.

LEONARD F. MILLER, former Head of Agricultural Economics at Oklahoma State University, has been appointed Dean, Imperial Ethiopian College, Dire Dawa. The College is being established by an Oklahoma State University Contract Team.

ROBERT R. MILLER, who recently completed requirements for the M.S. at Penn State, has accepted a position with the Mutual Federation of Independent Cooperatives at Syracuse, New York.

THOMAS A. MILLER, Farm Economics Research Division, ERS, is now stationed at Kansas State University, Manhattan.

JOSEPH E. MONTGOMERY is now Assistant Commercial Secretary of the Canadian Embassy at The Hague, Netherlands.

GARY D. MOORE has resigned as Assistant in Agricultural Economics at Auburn University to accept employment with the Fifth Farm Credit Administration District in New Orleans, Louisiana.

DAVID E. MOSER has been appointed Extension Associate Professor at the University of Missouri.

R. C. MUIRHEAD, formerly with the Agriculture Division of the Dominion Bureau of Statistics, is now with the office of the Senior Mathematical Advisor of the Bureau, where he will be concerned with the 1961 Census quality check.

YAIR MUNDLAK, of the Faculty of Agriculture of The Hebrew University of Rehovot, Israel, is on leave for the current academic year to do research and teaching as a visiting Associate Professor of Agricultural Economics at University of California, Berkeley.

WILLIAM G. MURRAY, Professor of Economics at Iowa State University, was on leave of absence from September 1 to October 15 to complete some land appraisals for the U. S. Department of Justice.

MAX MYERS returned to the staff of the Economics Department, South Dakota State College, on July 1.

RALPH NELSON has been granted a two-year leave of absence from South Dakota State College to go with ICA as Economic Advisor to the Ministry of Agriculture in Ankara, Turkey.

TED NELSON, Extension Economist, University of Nebraska, is on leave for Ph.D. graduate study at Oklahoma State University.

T. EVERETT NICHOLS has returned from educational leave at Duke University

to his position as Grain Marketing Specialist in the Department of Agricultural Economics at North Carolina State College.

GRAY N. NUCKOLS, JR., formerly Instructor in Agricultural Economics at the University of Maryland, has accepted a position as Agricultural Economist with the Farm Supplies Branch, Purchasing Division, of Farmer Cooperative Service.

FRANK PARKER, who retired in 1953 as Statistician in Charge of the North Carolina State Office of the Crop Reporting Service, has received an honorary Doctor of Science degree from North Carolina State College in recognition of his outstanding work in agriculture in that State.

EARL J. PARTENHEIMER, Department of Agricultural Economics at Auburn University, has been promoted to Associate Professor and Associate Agricultural Economist.

ARNOLD A. PAULSEN, Iowa State University was granted a year's leave of absence beginning September 1 to assist the Ford Foundation as a member of the Harvard Advisory Group in Iran.

DARREL H. PLAUNT has been appointed Assistant Professor in the Department of Agricultural Economics in the Ontario Agricultural College to undertake research, extension, and teaching in farm management.

JAMES S. PLAXICO has been appointed Head of the Agricultural Economics Department at Oklahoma State University.

RONALD H. POLLOCK, Ohio State University, was promoted to Assistant Professor July 1.

HOMER PRESTON, who has been Chief of the Fruit and Vegetable Branch of Farmer Cooperative Service since 1955, has been selected to fill a new position in that Agency, Assistant Director of the Marketing Division.

EDWARD QUINONES, formerly with the Fats and Oils Division, Foreign Competition Branch, of the Foreign Agricultural Service, USDA, became Assistant Agricultural Attache in Caracas, Venezuela, on October 1.

PHILIP M. RAUP has returned to the University of Minnesota after a year's sabbatical leave in Europe, where he studied land use changes in Europe and the United Kingdom.

ROBERT M. REESAR, Ohio State University, was promoted to Assistant Professor July 1.

ALLEN B. RICHARDS has been appointed Senior Operations Research Analyst with General Mills, Inc., in Minneapolis.

DONALD ROHDY is now on the staff of the Marketing Economics Division, ERS. He is stationed at North Carolina State College, Raleigh, where he will act as Regional Coordinator for the Southern Regional Livestock Marketing Research Committee. Until accepting this assignment, he was a graduate student at the Iowa State University.

J. R. ROUSH has been promoted to the rank of Associate Professor at the University of Illinois.

LEONARD W. SCHRUBEN returned to Kansas State University on July 1 after spending a year and a half as economic advisor with the Great Plains Market Development Association, Inc. He also conducted a series of meetings in foreign countries with the Grain Sorghum Producers' Association, a private trade group of Amarillo, Texas, which took him around the world.

JOHN W. SHARP, Ohio State University, was promoted to Professor July 1.

SOL. SINCLAIR, Professor and Head, Department of Agricultural Economics,

University of Manitoba, was recently a participant in the FAO conference on the "Economics of the Regulation of Fisheries."

JOHN SJO was promoted to rank of Associate Professor at Kansas State University on July 1.

D. G. SMITH has been promoted to the rank of Assistant Professor at the University of Illinois.

S. R. SMITH has been appointed Administrator of the Agricultural Marketing Service, USDA. He had previously been Director of the Fruit and Vegetable Division of AMS.

JOHN E. STAHL joined the staff of the Farm Economics Division, Economic Research Service, in June. After six months or so of preparatory work in Washington, he will carry on cooperative work in tenure investigations in Puerto Rico.

JOHN F. STOLLSTEIMER joined the staff at North Carolina State College as Assistant Professor in Agricultural Economics in July. He was formerly with USDA in Berkeley, California.

HERBERT STUTTS, formerly of the Marketing Economics Division, ERS, is now Assistant Registrar in the Office of the Registrar and Admissions, University of Maryland.

WILLIAM G. TOMEK, who has completed the requirements for the Ph.D. at the University of Minnesota, has accepted a position as Assistant Professor at Cornell University.

R. TRIFON, post-doctorate fellow, Department of Agricultural Economics of the University of Manitoba, is returning to Israel in October to join the staff of the University of Haifia.

OLAF A. TURNBULL, Minister of the Saskatchewan Government Department of Cooperatives, has been appointed Chairman of the Board of Cooperative Fisheries Limited, and of the Northern Cooperative Trading Services Limited, for the conversion of fish filleting plants and trading stores, constructed by the Government for the use of the native population of Northern Saskatchewan, to Cooperatives.

JOHN UNGER, Agricultural Estimates Division, Statistical Reporting Service, formerly stationed at Kansas, is now with the Washington staff of the Division.

ED UVACEK was appointed Livestock Marketing Specialist with the Extension Service at the Agricultural and Mechanical College of Texas, effective July 10. He replaces LLOYD BERGSMA, who is on a one-year leave of absence with the Southwest Cattlemen's Association at Ft. Worth, Texas.

LAWRENCE W. VAN MEIR, USDA, has transferred from the Denver Office to the Washington Office, where he is in charge of the Livestock, Fats and Oils Section of the Economic Research Service.

FRANCIS WALKER, formerly at Purdue University, has accepted a position as Assistant Professor of Agricultural Economics at Ohio State University. He will work in Production Economics.

HOWARD S. WATKINS, JR., joined the research staff of the Department of Agricultural Economics, University of Maine, with an instructor rating, July 1. The first year he will devote his time to the marketing of Maine blueberries.

FREDERICK V. WAUGH, Director of the Economic and Statistical Analysis Division of the Economic Research Service, USDA, has returned to duty following a year's leave on a Social Science Research Council Senior Research Award to study agricultural surplus problems.

WILLIAM A. WAYT, Ohio State University, was promoted to Associate Professor July 1.

ANNE WHEELER, a member of the Livestock and Wool Branch, Marketing Division, of Farmer Cooperative Service, retired on June 10, after nearly 42 years of Government service.

JAMES H. WHITE has returned to the University of Arkansas after completing residence requirements for the Ph.D. at Oklahoma State University.

NORMAN K. WHITTLESEY has been appointed a USDA Collaborator for the Farm Economics Research Division. He is stationed in the Department of Economics and Sociology at Iowa State University, where is he also continuing his graduate work.

G. P. WIBBERLEY, Wye College, University of London, is Visiting Professor of Land Economics at the University of Illinois for the fall semester.

PAUL WILKINS has been promoted to the position of Chief, Frozen Food Locker Branch, Purchasing Division, of Farmer Cooperative Service. In addition to his regular responsibilities with frozen food locker and provisioning firms, he is serving as Chairman of the FCS Committee on Cooperative Services for Small Farmers, which coordinates the work of the agency for the Rural Development Program.

S. W. WILLIAMS, Associate Professor of Agricultural Marketing, University of Illinois, and Cooperative Agent, Economic Research Service, USDA, is on leave from September through March to serve as research director for the New York Governor's Committee on Milk Marketing. This is a committee of eight college professors appointed by Governor Rockefeller to study problems and make recommendations for strengthening New York's dairy industry.

RUSSELL V. WITHERS has accepted appointment as Assistant Professor in the Department of Agricultural Economics at the University of Idaho. He had been doing graduate work at Cornell University.

ORGANIZATIONAL ANNOUNCEMENTS

Officers of the Canadian Agricultural Economics Society elected by ballot for the 1961-62 term are as follows: President, B. H. Kristjanson; Vice-Presidents, L. W. J. Hurd and A. W. Wood; Councillors, G. E. Ackerman, J. W. Clarke, D. Kirk, and S. L. Medlund.

The Economic and Statistical Analysis Division (formerly the Agricultural Economics Division) of the Economic Research Service, USDA, has been reorganized with the following Branches: Commodity Analysis, Outlook and Projections, Farm Income, Farm Population, and Agricultural History.

The U.S. Civil Service Commission announces that applications are now being accepted for the 1962 Federal Service Entrance Examination. This examination, open to college juniors, seniors, and graduate students regardless of major study, as well as to persons who have had equivalent experience, offers the opportunity to begin a career in the Federal Service in one of some 60 different occupational fields, including economics and agricultural economics, other social sciences, and statistics. A written test is required.

The positions to be filled from the FSEE are in various Federal agencies and are located in Washington, D.C., and throughout the United States. Depend-

ing on the qualifications of the candidate, starting salaries will be $4,345 or $5,355. Management Internships, with starting salaries of $5,355 or $6,435 a year, will also be filled from this examination.

Closing date for acceptance of applications for Management Internships is January 25, 1962. For all other positions, the closing date is April 26, 1962. Written tests are scheduled to be held on January 13, February 10, March 17, April 14, and May 12.

Details concerning the requirements, further information about the positions to be filled, and instructions on how to apply are given in civil service announcement No. 265. The announcement and application cards may be obtained from many post offices throughout the country, college placement offices, civil service regional offices, or from the U.S. Civil Service Commission, Washington 25, D.C.

WINTER PROGRAM OF THE AMERICAN FARM ECONOMIC ASSOCIATION, JOINT SOCIAL SCIENCE ASSOCIATION MEETINGS

New York, New York, December 26-29, 1961

Tuesday, December 26

8:00 P.M. Executive Committee Meeting

Wednesday, December 27

Morning Session

THE SCOPE OF FARMER COOPERATIVES

Chairman: GLEN W. HEDLUND, Cornell University

Papers: Present and Future
JOSEPH G. KNAPP, United States Department of Agriculture
Obstacles and Opportunities
D. B. DELOACH, University of California

Discussants: GLEN LAKE, Michigan Milk Producers Association
W. F. MUELLER, University of Wisconsin

Afternoon Session (Joint with American Economic Association)

RURAL POVERTY AND NATIONAL POLICY

Chairman: WILLIAM H. NICHOLLS, Vanderbilt University

Papers: Economic Security for Agricultural Labor
LOUIS LEVINE, United States Department of Labor
Relations of the Low Income Farm Problem to Major National Economic Problems
WILLIAM E. HENDRIX, United States Department of Agriculture

Discussants: LEONARD P. ADAMS, Cornell University
JOHN G. MCNEELY, Agricultural and Mechanical College of Texas

Thursday, December 28

Morning Session

THE FAMILY FARM IN DOMESTIC AND FOREIGN LAND TENURE POLICY

Chairman: JOHN BLACKMORE, University of Massachusetts

Papers: Problems in Domestic Policy
MARSHALL HARRIS, State University of Iowa
Problems in Foreign Policy
ERVEN LONG, U. S. International Cooperation Administration

Discussants: PETER DORNER, University of Wisconsin
HOWARD E. CONKLIN, Cornell University

Afternoon Session (Joint with Econometric Society)

MEASURING SOCIAL COSTS OF ALTERNATIVE AGRICULTURAL PROGRAMS

Chairman: GEORGE G. JUDGE, University of Illinois

Papers: Analytic Framework for Measuring Social Costs
MARTIN J. BAILEY, University of Chicago
Measures of Social Costs of Agricultural Programs
T. D. WALLACE, North Carolina State College

Discussants: JAMES P. CAVIN, United States Department of Agriculture
LEONID W. HURWICZ, University of Minnesota

6:30 P.M. Dinner Meeting of AFEA members

Speaker: HENRY A. WALLACE
A New Dealer Looks at the New Frontier

Friday, December 29

Morning Session (Joint with American Marketing Association)

THE FOOD STAMP PLAN

Chairman: FREDERICK V. WAUGH, United States Department of Agriculture

Papers: A Progress Report
HOWARD P. DAVIS, United States Department of Agriculture
Some Reactions of the Food Trade
S. KENT CHRISTENSEN, National Association of Food Chains
Discussants: ROBERT C. KRAMER, Michigan State University
JOHN M. RATHMELL, Cornell University

Afternoon Session (Joint with American Statistical Association)
FARMS AND FARMERS FOR STATISTICAL PURPOSES
Chairman: HARRY C. TRELOGAN, United States Department of Agriculture
Papers: Census Concepts; Past, Present and Future
RAY HURLEY, United States Department of Commerce
Analytical Concepts; Changes Induced by Technologic and Economic Developments
NATHAN M. KOFFSKY, United States Department of Agriculture
Discussants: J. E. PALLESEN, Kansas Agricultural Statistician
LEE R. MARTIN, University of Arkansas

EMPLOYMENT SERVICE

By arrangement with the Professional Placement Center of the New York State Employment Service, placement services will be provided during the meeting. The Placement Area in the hotel will be announced in the printed program distributed at the meeting. Listings of the vacancies and of applications of those seeking positions in economics, statistics, market research, programming and teaching will be available for review. Facilities for interviewing will be provided. Placement services cannot be extended to persons not attending the meeting.

The Center is asking for the cooperation of the state employment services throughout the country for preconvention registration of applications and openings. To take advantage of these services, those planning to attend the meeting should take the following steps.

Candidates should visit the nearest local office of their state employment service and request that their applications be processed for the convention placement service at the annual meeting of the Allied Social Science Associations. *The deadline for filing is December 11.* They should request that their applications be sent in triplicate to the Professional Placement Center of the New York State Employment Service, 444 Madison Avenue, New York 22, New York. They should prepare typed resumes, in triplicate, not larger than 8½ × 11, using one side of the sheet only, and request the local employment office to attach these resumes to their applications. Additional copies should be brought to the convention for use in interviews.

Employers should contact the nearest local office of their state employment service and request that their orders be processed for the convention placement service at the annual meeting of the Allied Social Science Associations. *The deadline for filing is December 11.* They should request that five copies of their orders be sent to the Professional Placement Center of the New York State Employment Service, 444 Madison Avenue, New York 22, New York.

Employers and candidates desiring placement assistance at the convention should check with the Placement Area immediately on arrival to confirm their registration and convention addresses. Employers may arrange for interviewing space at this time.

Applications and orders will be accepted during the convention in the Placement Area. However, processing will delay availability for review. Candidates and employers will therefore find it to their advantage to file in advance.

LAND AND WATER USE SYMPOSIUM

WITH SPECIAL REFERENCE TO MOUNTAIN AND PLAINS REGION

Section 0, American Association for the Advancement of Science

In Cooperation with
The American Farm Economic Association
and Other Societies
Denver, Colorado, December 27 and 29, 1961
Grand Ballroom, Denver Hilton Hotel

Wednesday, December 27

I. LAND AND WATER RESOURCES (9 a.m. to 12 noon)
Chairman—ROLAND RENNE, President, Montana State University
Population Demands for Land and Water Resources of the Western Hinterland
S. C. SMITH, University of California
Land Resources and Potential Use
R. D. HOCKENSMITH, Soil Conservation Service
Water Resources, Development and Uses
W. I. PALMER, Department of the Interior
Public Grazing Lands in the Economy of the West
M. L. UPCHURCH, Economic Research Service, USDA

II. OPTIMUM USES FOR RESOURCES (1:30 to 4:30 p.m.)
Chairman—E. F. FROLIK, Dean, College of Agriculture, University of Nebraska
Criteria and Planning for Optimum Use
E. N. CASTLE, Oregon State University
Economic Priorities on Water Use in Arid Regions
NATHANIEL WOLLMAN, University of New Mexico
Agriculture as a Competitive Segment of Multiple Use
B. D. GARDNER, Brigham Young University
Recreation as a Competitive Segment of Multiple Use
MARION CLAWSON, Resources for the Future, Inc.

Friday, December 29

III. IMPACT OF PUBLIC POLICY ON LAND AND WATER USE (9 a.m. to 12 noon)
Chairman—W. E. MORGAN, President, Colorado State University
The Government's Responsibility for Land and Water
L. B. LEOPOLD AND R. L. NACE, U. S. Geological Survey
Problems and Policies Associated With Wilderness Areas and Other Reserves of Public Lands
C. R. GUTERMUTH, Wildlife Management Inst.
Problems Growing Out of the Spaciousness of the West
M. M. KELSO, University of Arizona
Public and/or Private Investment in Resource Development
W. E. FOLZ, University of Idaho

IV. PROJECTING MANAGEMENT PROGRAMS (1:30 to 4:30 p.m.)
Chairman—R. E. HODGSON, Director, Animal Husbandry Research Division, ARS
Providing for Multiple Use in Managing Land and Water
J. A. HOPKIN, Bank of America
Modifying Management and Vegetation of Watershed Areas for Improved Water Yields
F. H. KENNEDY, U. S. Forest Service
Management Associated with Complex Use for Wildlife, Livestock, and Recreation

A. L. McComb, University of Arizona
Managing Private Lands in Relation to Changing Uses of Public Lands
N. Keith Roberts, Utah State University

On Thursday morning (9 a.m. to 12 noon), December 28, a general symposium on *Water and Climate* has been arranged by the Committee on Desert and Arid Zones Research, Southwestern and Rocky Mountain Division, AAAS, and Section 0 of the Association.

THE AMERICAN FARM ECONOMIC ASSOCIATION AWARDS FOR RESEARCH IN AGRICULTURAL ECONOMICS, 1962

To recognize and encourage meritorious research in agricultural economics, seven awards of $250 each will be presented in 1962 by the American Farm Economic Association. In addition, three awards of $100 each will be presented for Master's degree theses.

Selections for the awards will be made from published research, Ph.D. theses, and M.S. theses submitted for consideration in accordance with the procedures outlined below. No one may receive an award in the same category more than once every three years.

Awards for Published Research

1. Three $250 awards, each in a different field of agricultural economics, will be made for publications including bulletins, articles, pamphlets and monographs (textbooks are ineligible) classified in the following categories:

(a) Farm management and production economics
(b) Agricultural marketing
(c) Agricultural prices
(d) Agricultural finance
(e) Land and water economics and conservation
(f) Theory and methodology
(g) Agricultural policy
(h) General agricultural economics

2. Persons submitting items should indicate the field in which they believe the reports should be classified.

3. Selections will be made from published research bearing the publication date of 1961.

4. Eligible recipients must be less than 41 years of age at the time of publication.

5. Members of the Awards Subcommittee for Published Research will not be eligible to submit papers of their own.

6. Each published report may receive only one award presented by the American Farm Economic Association in 1962. An entry may, however, be entered in more than one of the following categories: (a) Best article appearing in the *Journal of Farm Economics;* (b) Published research; and (c) Ph.D. thesis.

7. Ten copies are requested of each publication submitted for consideration. Fewer copies will be accepted in such cases as articles appearing in national journals available to the judges. In no event should less than three copies be sent.

8. The Awards Subcommittee for Published Research will consist of nine persons, in addition to the Chairman, representing the various designated fields. The members of the Subcommittee, all of whom will serve as judges, are:

Ronald L. Mighell, Economic Research Service, USDA
Arval Erikson, Oscar Mayer & Company
William F. Henry, New Hampshire State University
Rex F. Daly, Economic Research Service, USDA
Donald C. Horton, Bureau of the Budget
Howard E. Conklin, Cornell University
J. A. Nordin, Kansas State University
Boris Swerling, Stanford University
Lee R. Martin, University of Arkansas

9. Publications should be sent directly to the Chairman of this Subcommittee, Kenneth L. Bachman, Economic Research Service, U. S. Department of Agriculture, Washington 25, D.C., *on or before March 15, 1962.*

Awards for Ph.D. Theses

1. Three $250 awards will be made for theses prepared by candidates for the Ph.D. degree in any department of Economics or Agricultural Economics.

2. An entry must be submitted by the head of the department to which the thesis was presented in partial fulfillment of requirements for a degree. A department may submit one thesis for each eight Ph.D. theses or fraction thereof presented to a graduate school faculty in 1961.

3. Selection will be made from theses approved in final form by the student's advisory committee during the calendar year 1961 provided the candidate has met all other formal requirements for the Ph.D. degree.

4. A published thesis may be entered in both the published research and thesis classes but will be eligible for only one award. Although a published thesis is acceptable, a copy of the thesis as submitted to the graduate faculty should be sent whenever possible.

5. Only one copy of an unpublished thesis will need to be sent to the Committee Chairman for consideration; however, if two or three are available it will expedite the judging. All copies will be returned after they have been read by the judges.

6. The Awards Subcommittee for Ph.D. Theses will consist of three persons, in addition to the Chairman. These three persons, all of whom will serve as judges are:

James Bonnen, Michigan State University
R. F. Hutton, Pennsylvania State University
Vernon Ruttan, Purdue University

7. Theses should be sent directly to the Chairman of this Subcommittee, Geoffrey S. Shepherd, Department of Agricultural Economics, Iowa State University, Ames, Iowa, *on or before March 15, 1962.*

Award for Best Article in Journal of Farm Economics

As has been the practice for a number of years, the Editors and Editorial Council of the *Journal of Farm Economics* will again choose the most outstanding article published in the *Journal* during the preceding calendar year (in this instance 1961). The amount of this award is $250.

Awards for M.S. Theses

1. Three $100 awards will be made for theses prepared by candidates for the M.S. degree in any department engaged in training agricultural economists at the Master's degree level.

2. An entry must be submitted by the head of the department to which the thesis was submitted in partial fulfillment of requirements for a degree. No department may submit more than one thesis for consideration.

3. Selections will be made from theses presented to a graduate school faculty during the calendar year 1961.

4. Only one standard typewritten copy as submitted to the graduate faculty need be sent to the Committee Chairman for consideration, but if two copies can be sent, it will be appreciated by the Committee. All copies will be returned after the Committee has completed its work.

5. The Awards Subcommittee for M.S. Theses will consist of three persons in addition to the Chairman. These three persons, all of whom will serve as judges, are:

Robert G. F. Spitze, University of Illinois
T. E. Tramel, Mississippi State University
Edward H. Ward, Montana State College

6. Theses should be sent directly to the Chairman of this Subcommittee, Richard A. King, North Carolina State College, Raleigh, North Carolina, *on or before March 15, 1962.*

Announcements of the 1962 awards will be made at the 1962 annual meeting of the American Farm Economic Association. Names of the recipients of the 1961 awards will appear in the Proceedings Issue of the *Journal of Farm Economics.*

These awards are financed in part from funds donated by persons and firms interested in advancing research and scholarship in Agricultural Economics. The funds and programs are administered by the American Farm Economic Association. General inquiries, and requests for additional copies of this announcement, should be directed to the Chairman of the Awards Committee, George K. Brinegar, Department of Agricultural Economics, University of Illinois, Urbana, Illinois.

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The Bethlehem-Youngstown Case .....*L. S. Keyes*
A Theory of Optimum Currency Areas .....*R. A. Mundell*
Contributors to Three Professional Journals .....*P. A. Yotopoulos*

The AMERICAN ECONOMIC REVIEW, a quarterly, is the official publication of the American Economic Association. Annual dues or subscriptions are six dollars. Address editorial communications to Dr. Bernard F. Haley, Editor, AMERICAN ECONOMIC REVIEW, Stanford University, Stanford, California. For information concerning other publications and activities of the Association communicate with the Secretary-Treasurer, Dr. James Washington Bell, American Economic Association, Northwestern University, Evanston, Illinois. Send for information booklet.

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Residence Histories and Exposure Residences for the United States Population .....*Karl E. Taeuber, William M. Haenszel and Monroe G. Sirken*
Testing the Independence of Regression Disturbances .....*Henri Theil and A. L. Nagar*

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